STATE GEOLOGICAL SURVEY OF KANSAS

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BULLETIN 15

The Geology of Cloud and Republic Counties, Kansas

BY

MONTA E. WING

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The Geology of Cloud and Republic Counties, Kansas.

By Monta E. Wing.

INTRODUCTION.

THIS bulletin contains the results of a geologic survey of Cloud and Republic counties made during the summer of 1929. The work was begun in Cloud county, and extended into Republic county, which contains the same rock formations, salt swamps, coal deposits and other geologic features. The field work was of a reconnaissance nature, and the contacts between the formations were sketched on topographic maps issued by the United States Geological Survey. The results of the survey are of considerable scientific and economic interest. One new formation is described. Among the economic resources water, soil and petroleum are given the most attention, although important sand, gravel and clay deposits are also considered. The chief results of the survey, however, are general. Geologic formations appearing at the surface and topographic features, such as the hills and valleys, are described and their origin given, thereby increasing the appeal which normally comes from observation of these features. The principal events in the geologic history of the area are listed, with special emphasis on the forces that have changed the surface and the tremendous amount of time involved. While the report contains many things of scientific interest the attempt is made to interest a large number of readers rather than only a few. Consequently, terms that would not be understood except by a geologist are not used, and many explanations that might be unnecessary for the geologist are given.

Acknowledgments.

Unusual interest has been shown in the survey of Cloud and Republic counties, not only by officials but by other individuals. The writer is indebted particularly to many farmers in the area who gave information concerning water wells and other geologic features; to Representative Frank Carlson, of Concordia, and Senator Robert Hanson, of Jamestown; to John Swenson, William O'Reilly and James O'Rourke, of Concordia, and George Palmer, of Miltonvale,

who furnished well logs and other data; and to A. F. Ries, of the Throckmorton-Ries Construction Company, Fort Scott, Kan., who supplied certain information concerning gravel deposits near Glasco. In Republic county the writer was assisted materially by W. M. Slopansky, city manager of Belleville, and by the county commissioners, E. L. Shepard, E. P. Ahrens and T. W. Lowe. The report was prepared in the State Geological Survey office at Lawrence, where the writer received help from the staff, including especially Drs. Raymond C. Moore, K. K. Landes and J. W. Ockerman. Arthur Lyon, of Beloit, Wis., assisted with the field work.

GEOGRAPHY AND TOPOGRAPHY.

Republic and Cloud counties lie in the first and second tiers of counties respectively from the north border of the state and a short distance east of its center. Each includes a rectangular area 24 by 30 miles with the longer dimension in an east-west direction. Concordia is the county seat of Cloud county, and Belleville of Republic county. In addition, there are the smaller towns of Glasco, Miltonvale, Clyde, Aurora, Ames and Jamestown, in Cloud county, and Scandia, Courtland, Republic City, Munden and Cuba, in Republic county. Warwick, Byron and Chester are along the north line of Republic county, but principally in Nebraska.

Railroads. Both counties have exceptionally good transportation facilities. The towns along the northern edge of Republic county are on the main line of the Chicago, Burlington & Quincy railroad between St. Louis and Denver, while a branch of this road runs southwestward through Cuba to Concordia. The Chicago, Rock Island & Pacific railroad crosses Republic county, running east through Courtland and Scandia to Belleville, where it divides, one branch going northeast through Munden and Narka and the other southeast through Cuba and Clyde. A branch line of the Atchison, Topeka & Santa Fe cuts across the two counties diagonally from southeast to northwest connecting Miltonvale and Aurora with Concordia and extending on through Courtland to Superior, Neb. The Missouri Pacific railroad serves all of the towns in the Republican river valley and has a branch west from Concordia through Jamestown. Branches of the Union Pacific connect Belleville and Talmo, and Concordia and Clyde with the main line farther east, while another branch extends up the Solomon river through Glasco. Thus the area here described is served by a total of ten branch or mainline railroads belonging to five of the principal systems.

GEOLOGIC MAP OF CLOUD COUNTY, KANSAS

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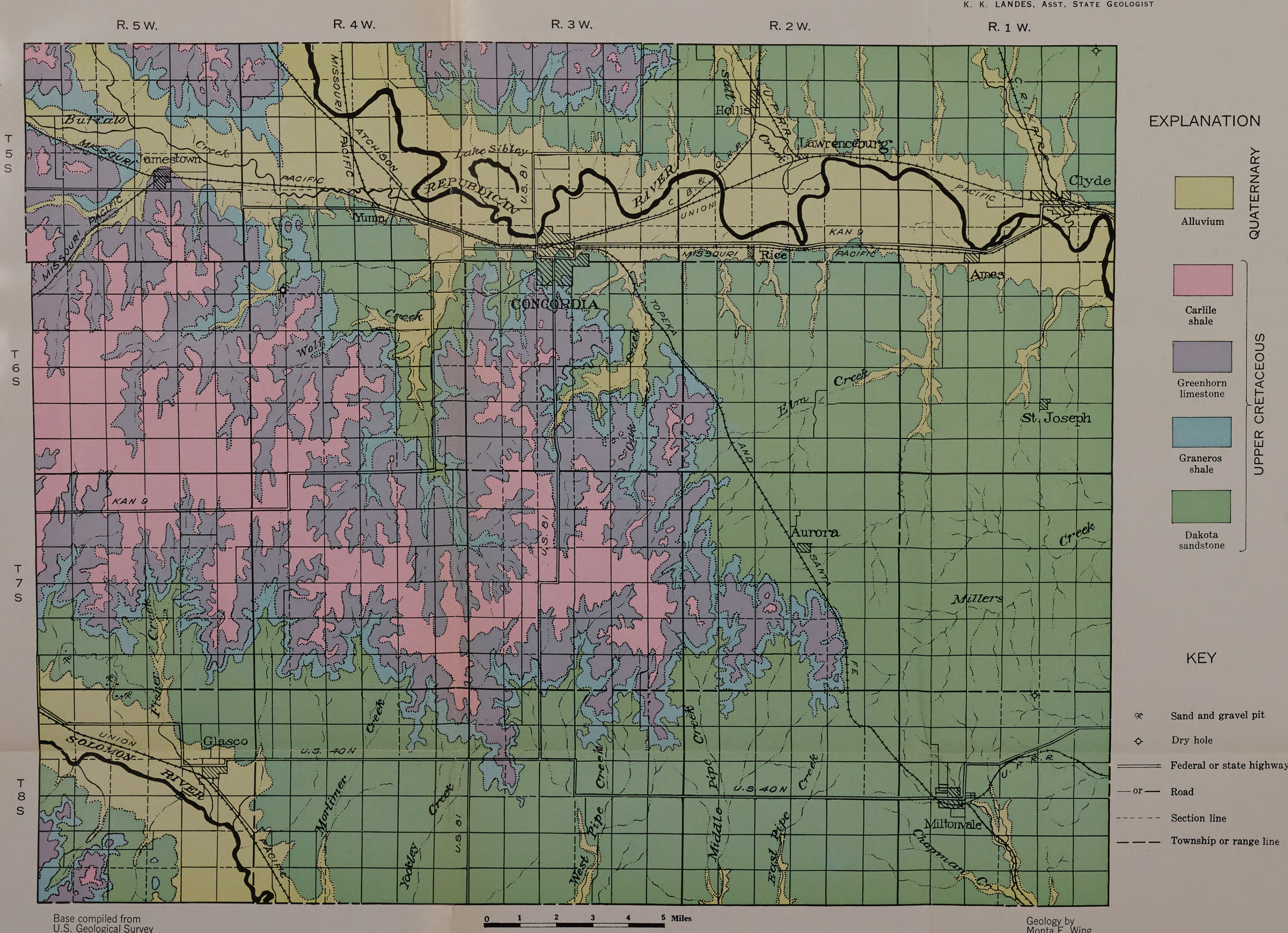

BULLETIN 15, PLATE I

GEOLOGIC MAP OF REPUBLIC COUNTY, KANSAS

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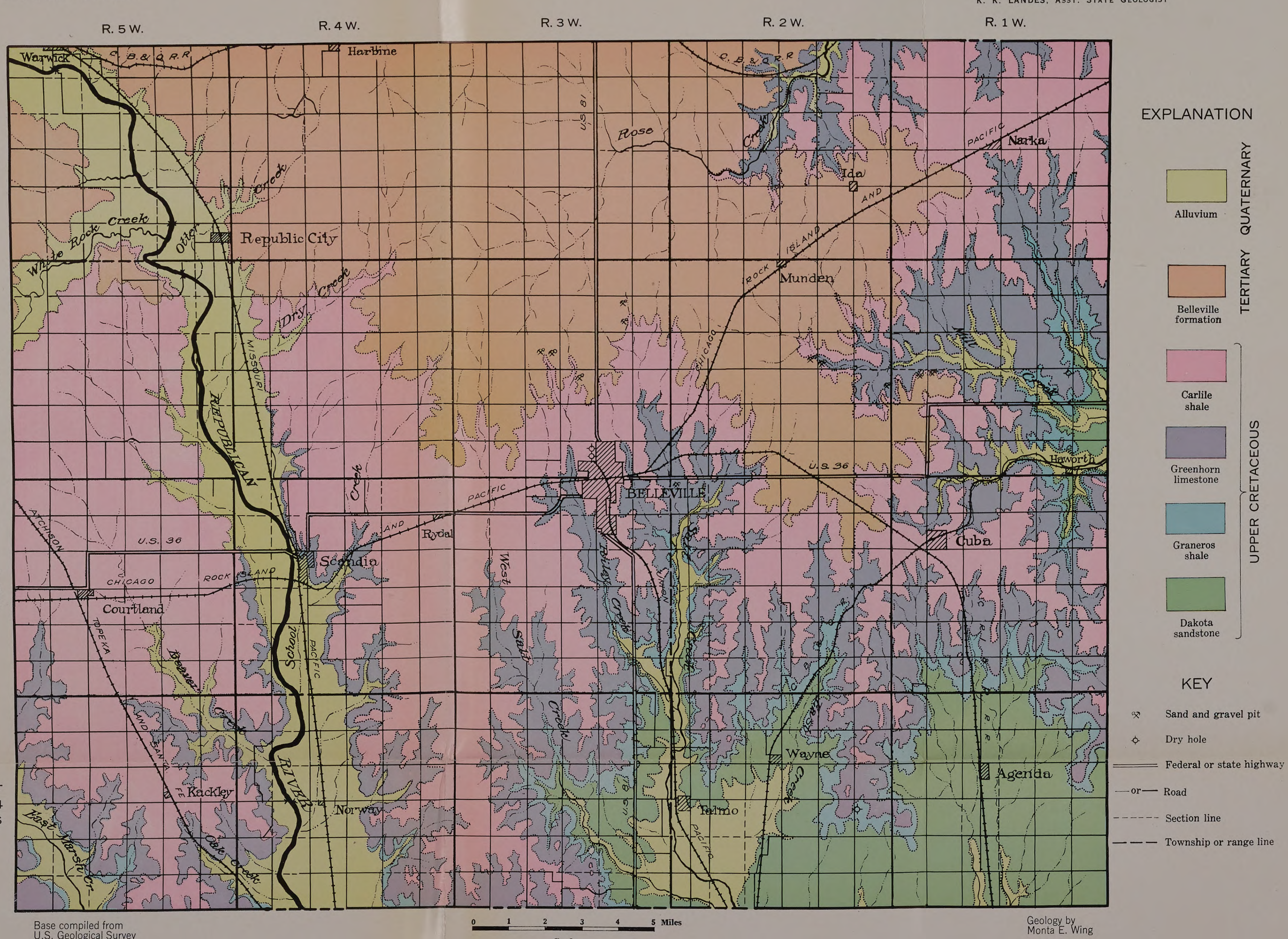

Base compiled from
U.S. Geological Survey
Topographic maps

Geology by
Monta E. Wing

BULLETIN 15, PLATE II

Highways. In addition to the railroads, state and national highways cross both counties from north to south and from east to west and offer easy access to the area by automobile from all directions. Federal highway No. 81, through Concordia and Belleville, is one of the important north-south routes across the country, connecting Winnipeg, Canada, with Laredo, Tex., on the Mexican border. Federal highway No. 40 north, which is one of the alternate routes through central and western Kansas on the Victory highway connecting Baltimore, Md., and San Francisco, Cal., passes through Cloud county from Miltonvale to Glasco. Federal highway No. 36

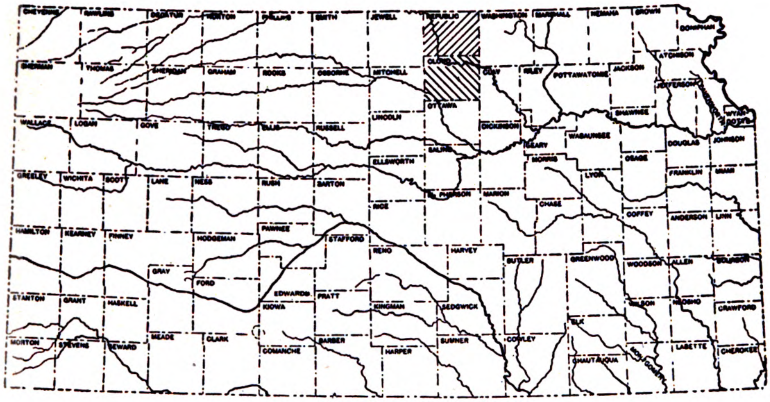

Fig. 1.—Index map of Kansas, showing location of Cloud and Republic counties.

runs through Belleville, Scandia and Courtland, in Republic county. While not as prominent nationally as U. S. 40 north, it connects with that highway near Colby and is one of the principal routes through northern Kansas. It is paved for a short distance west of Scandia. The remainder of the national highway system in these counties is graveled, and by constant maintenance is kept in excellent condition. State highways No. 9 and 28 connect Concordia with Clyde and other towns to the east and with Jamestown, Beloit and towns farther west. Each county has also a good system of county roads.

Agriculture is the most important industry in the area. Small grains, chiefly wheat, and corn are the principal crops on the flat uplands and in the valleys, while the rougher areas are used for grazing. Dairying has been growing in importance the last few years.

Topography. The topography of Cloud and Republic counties presents a wide variety of types. There are the high, extremely flat uplands resembling the Great Plains farther west, the gently rolling Dakota area of eastern Cloud county, the broad flat valleys of the Solomon and Republican rivers and, between the uplands and lowlands a very rough belt consisting of deeply dissected uplands. (Plates V and VI.) Subordinate but interesting topographic features are the sandstone knolls, river terraces and salt marshes. The highest sandstone knolls are the steep-sided twin mounds covered by large irregular blocks of brown sandstone approximately 10 miles southeast of Concordia. Mounds of this character are common in the Dakota sandstone area. River terraces, as prominently developed along the Republican, consist of flats or benches on the sides of the valley, approximately 20 feet above the lower flood plain and separated from it by a steep slope. Excavations and cuts in the terraces show that they are mainly composed of sand and gravel overlaid by silt and soil. It is the remaining part of an older and higher flood plain of the Republican left there when the river in relatively recent times cut a deeper channel and built a new flood plain at a lower elevation. Because of the rich alluvial soil, its flatness and drainage the terrace contains the best farm land in the area.

Salt marshes are found northwest of Jamestown in Salt Marsh creek and in the valley south of Wayne and Talmo. In these localities the valley is unusually wide, the valley flat is marshy and the water is salty, leaving a white coating on the surface during dry months. The marsh near Jamestown lies in the Graneros shale, while the one near Wayne is at least 100 feet lower stratigraphically, which places it in the upper shale member of the Dakota sandstone. (See description of formations.) Occurrence of marshes at these horizons and the known presence of salt in the shales suggests that easily soluble salt caused rapid erosion and unusual widening of the valleys at those points where the stream cut into the shale. The width of Buffalo creek near Yuma, six miles east of Jamestown, indicates that the stream first penetrated the salt shale at this point and that, as the creek cut its valley lower, the swamp migrated up stream until it reached its present location four or five miles northwest of Jamestown. Buffalo creek has an extremely low slope or gradient—lower than that of the Republican river into which it flows. Consequently silt and dirt washed into the valley have covered and completely hidden the old marsh throughout most of its length. Slope wash and creek fill have encroached on the marsh

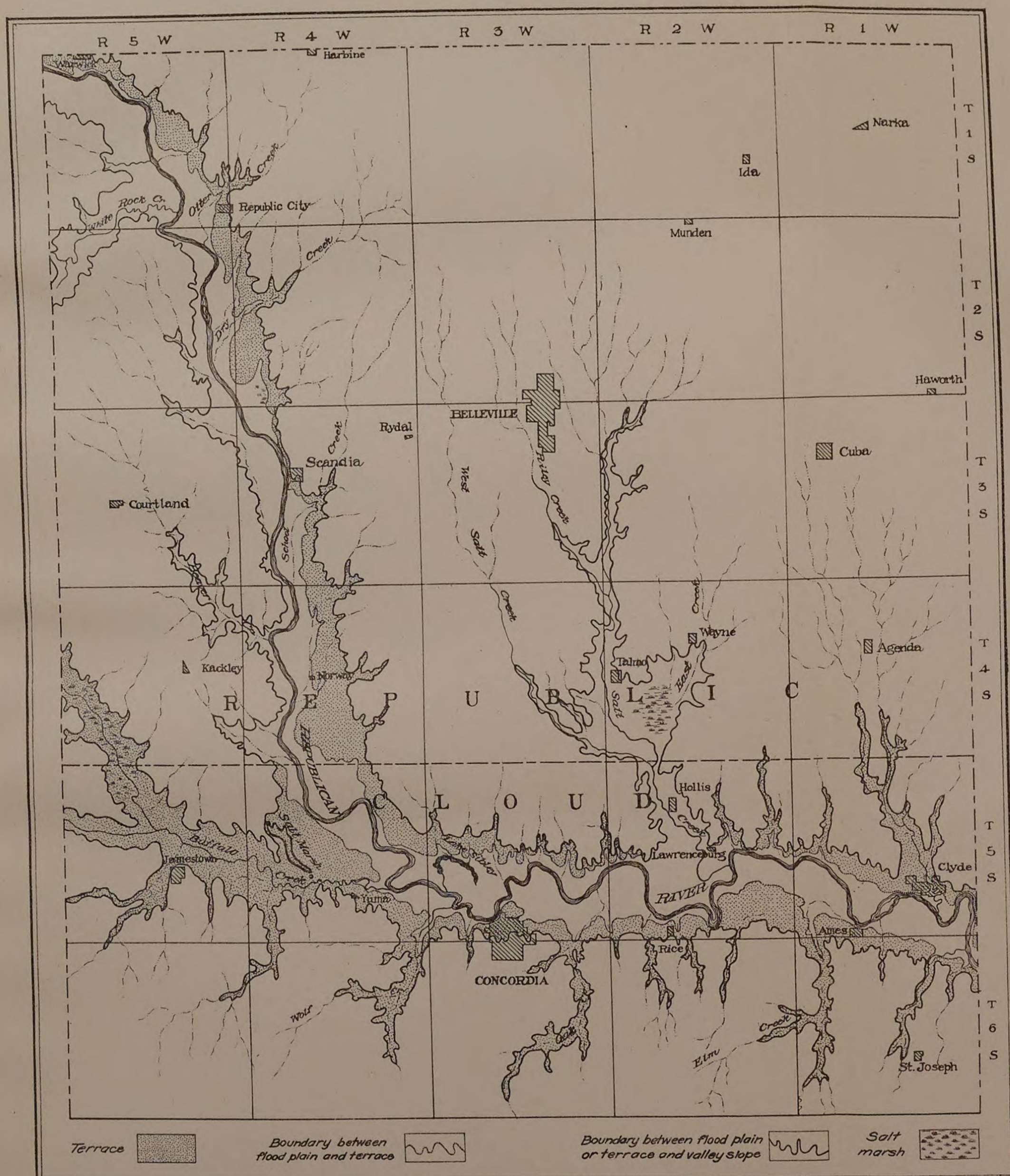

PLATE III.—Map of lower flood plain and terrace of Republican river.

near Wayne to such an extent that it is now less than one-fourth of its original size. Salt Marsh creek, north of Jamestown, has been dammed recently and the marsh converted into a broad shallow lake for hunting. The large amount of silt washed into the basin will in a relatively short time entirely fill the lake, creating a flat surface comparable to a flood plain.

PLATE IV.—Salt marsh lake northwest of Jamestown, Cloud county.

GEOLOGIC FORMATIONS.

Geologic time is extremely long. The most tangible indication of this is the thousands of feet of sediment that have been deposited in most parts of the world. The shales of to-day were formed by the deposition and later consolidation of clay or silt carried into the sea by ancient streams. Sands transported in a similar manner became sandstones. The limestones were formed by the accumulation of calcium carbonate on the sea floor. This compound was carried into the sea in solution and was removed either by animals for the building of shells or by chemical precipitation. Our modern rivers are likewise transporting sand, silt, clay and calcium carbonate, which are deposited on the ocean floor, and the slowness of this deposition gives us some inkling as to the length of time which must have been necessary to build up a series of sedimentary formations hundreds and even thousands of feet thick.

Deposition of sediment is not going on everywhere. On the lands wind and water are removing the rock as it decomposes or disintegrates. In general all areas of the continent above sea level are being eroded, while those areas beneath the sea receive sediment. A study of the rock formations in Kansas shows that there were not only long periods during which the state was covered by the sea, and sand, gravel, silt and lime were being deposited, but there were ex-

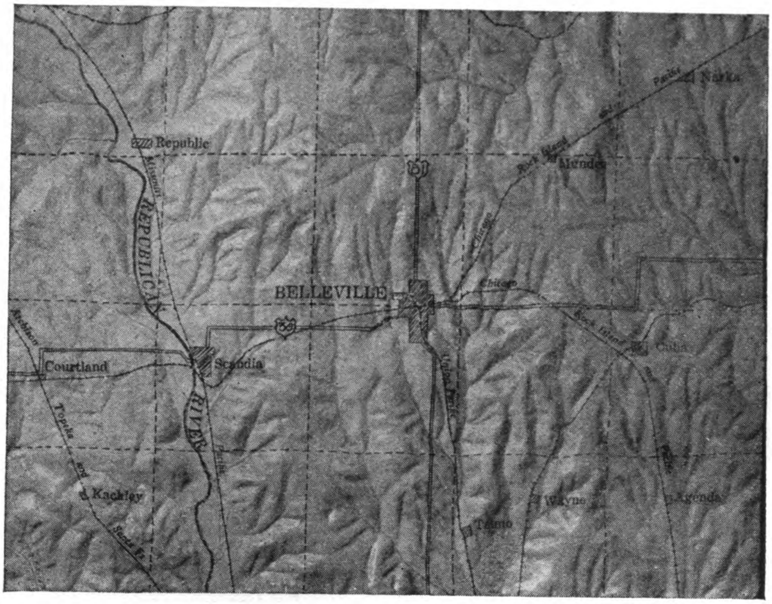

PLATE V.—Relief model of Republic county.

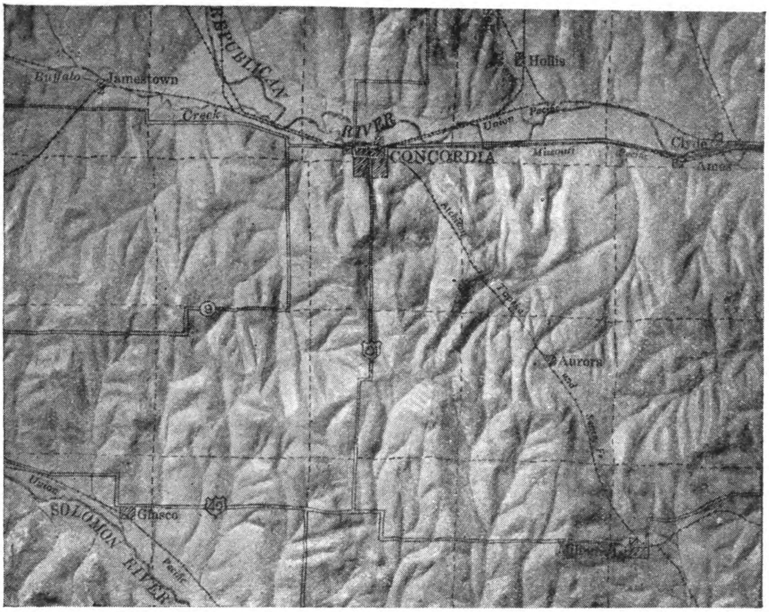

PLATE VI.—Relief model of Cloud county.

tremely long times, also, during which the area was dry land and was eroded in exactly the same manner as the wearing away of the rocks by wind and water at the present time.

Geologic time may be divided into eras and periods. Eras are the major divisions and may be hundreds of millions of years in length. They are separated from each other by times of unusual crustal disturbance, when the continents were elevated and suffered more or less prolonged erosion. Mountains formed by the deformation of previously deposited rock strata were in some cases obliterated before deposition of sediments on the land was resumed. Periods are shorter than eras and they are separated from each other by lesser disturbances within the earth which cause the seas to shift and in most cases withdraw from the continent. A typical period is represented by thick beds of marine origin separated from beds above and below by an old surface of erosion, called an unconformity. The rocks deposited during a period contain fossils characteristic of the life of that particular time and show whether the beds were formed in the sea or on the land. Subdivisions of periods may be called epochs.

The table on page 12 shows the eras and periods of geologic time and the classification of the formations exposed at the surface in Cloud and Republic counties.

Reference to the chart will show that the formations exposed in Cloud and Republic counties belong to the Cretaceous, Tertiary and Quaternary periods. The last-named includes the Pleistocene, when the northern part of North America was repeatedly covered by glacial ice, and the Recent, which includes all of the time that has elapsed since the ice disappeared. The Tertiary is the period before the Pleistocene, when there was rapid erosion in the Rocky Mountains and spreading of thick sands and gravels by streams over the neighboring lowlands.

During the Cretaceous, alone, of the periods represented by outcropping rocks in Cloud and Republic counties, was Kansas covered by the sea. This is indicated both by the composition of the Cretaceous rocks and by fossils such as shark teeth, vertebræ of marine reptiles, and shells of marine invertebrates in the sediments of that age. The withdrawal of the seas and the folding of the Rocky Mountains at the close of the period initiated the rapid erosion of the Tertiary. Climatic and other changes, due to the radical change in the earth's surface, caused the decline of the dominant reptilian life of the Mesozoic and led to the rapid development of the mammals during the Cenozoic.

Table of geologic time divisions.

Era.	Period.	Epoch.	Rock divisions in area.	Summary of events.
Cenozoic. "Recent life" (Age of mammals.)	Quaternary.	Recent.	Surficial deposits such as sand and alluvium of the flood plains, loess and dune sand.	Erosion by wind and water. Deposition of silt, sand and gravel by streams and silt and sand by the wind.
		Pleistocene.	Gravel beds, loess.	Ice covered northern part of North America, including northeastern Kansas. Beginning of present drainage lines. Extensive erosion of older deposits. Deposition of gravel and sand in valleys.
	Tertiary.	Pliocene. Miocene.	Belleville formation, consisting of sand, gravel and clay.	Uplift and rapid erosion of Rocky Mountains with widespread deposition over Great Plains as far east as Republic county.
		Oligocene. Eocene.	Not represented.	Erosion of the land in this region.
Mesozoic. "Middle life" (Age of reptiles.)	Cretaceous.		Carlile shale. Greenhorn limestone Pfeifer shale, Jetmore limestone, Lower Greenhorn. Dakota formation.	Deposition of sand, silt and calcium carbonate in shallow sea covering present area of Great Plains. Sandstone, shale and limestone formed from these sediments.
	Jurassic. Triassic.		Not represented.	Erosion of the land surface in this region.
Paleozoic. "Ancient life" (Age of invertebrates.)	Permian. Pennsylvanian. Mississippian. Devonian. Silurian. Ordovician. Cambrian.		Red beds, marine shale, limestone and sandstone (concealed below the surface).	Deposition of marine beds penetrated by deep wells in Cloud and Republic counties.
Proterozoic. (Primitive life.)	Commonly referred to as Pre-Cambrian. Probably represents more than one-half of geologic time.			
Archeozoic. (Beginning of life.)				

Quaternary.

Recent.

Flood-plain Deposits. The youngest deposits in Cloud and Republic counties are those formed by the present streams and by the wind. The former consist largely of sand and silt deposited over the flood plain in time of flood or under normal conditions in the channel of the stream. Beneath the finer surface deposits are layers of sand and gravel slightly older but of similar origin. These materials have a maximum estimated thickness in the Republican and Solomon river valleys of 50 to 60 feet. Laterally the flood plain deposits merge with the slope wash of the sides of the valley or with the loess or silt deposited by the wind on the bluffs.

In Cloud county the smaller valleys are partially filled with alluvium consisting of silt and clay. This is material derived from the uplands and washed into the valleys in relatively recent times. In Republic county the upland deposits consist of sands and clay, and consequently the creek valleys show a fill consisting of these materials which, in the western half of the county particularly, has a depth of 30 to 40 feet. An excellent exposure of such material may be seen along the creek a mile north and three-fourths of a mile west of Belleville in a bluff south of the road, where the following section was measured:

Section of creek fill near NW cor. of sec. 34, T. 2 S., R. 3 W.

	Ft.	In.
6. Soil	2	..
5. Silt, gray, calcareous. This material is structureless but contains numerous root holes through which water has circulated and has stained the silt a rusty brown	8	..
4. Silt, gray, which is very fine-grained and breaks into conchoidal blocks,	2	..
3. Clay, gritty. This shows horizontal bedding and contains brown rusty layers	2	..
2. White calcareous material	..	2
1. Clay, sandy. This bed is gray in color, and in addition to being sandy, contains bits of shell weathered from older formations, and also shells of fresh-water snails or gastropods	3	..

The fresh-water gastropod shells in the lowermost division of this section are of recent origin, so all of the deposits here described are classed as Recent. The valley filling may, however, have begun as early as the Pleistocene and is undoubtedly going on at the present time.

Eolian Deposits. Recent wind deposits consist of loess and dune sand. Scattered sand dunes are found in both Cloud and Republic counties, but are not common. A number of small dunes lie in Republican river valley near Lawrenceburg, while a more prominent one is found east of the Republican four miles south of Norway. An unusually large dune, more than 60 feet in height, occurs 3 miles northwest of Scandia and west of the river. It is clear from the location of these dunes that the almost pure quartz sand of which they are composed came from sand bars along the bank of the river. From this source the sand was carried to its present location by the wind. Dunes in some areas migrate through the movement of the sand from one side of the dune to the other, but the ones that have been mentioned are covered with vegetation and are stationary. There are small areas in Republican river valley, however, where river sand is being blown and is not only making travel over some of the side roads difficult but is also covering valuable farm land. The most interesting dune topography is found along Otter creek, 3 miles northeast of Republic City, in Republic county. Here the dunes are small but are closely spaced and cover an area approximately 3 miles long and from one-half to a mile in width. There are no roads across this area, partially because of the difficulty of building and maintaining them, and also because the land is only suited for grazing, and there are consequently few houses in the area. The sand originates through the erosion by wind and water of the sandy formation underlying the uplands. Otter creek valley, with its steep sides, short rugged tributaries, and especially its sand dunes, presents a striking contrast to the fertile, almost flat farm lands surrounding it.

Pleistocene.

The Pleistocene is the period during which ice accumulated to such a depth over great areas in Canada and the northern United States that it moved outward in all directions, but principally toward the south, where lobes of ice extended down the principal drainage channels. From the alternation of deposits of material carried by the ice with layers of soil formed during warmer intervals, geologists conclude that the accumulation of ice occurred at least five times. Deposits of clay, sand, gravel and bowlders in the northeastern part of Kansas belong mainly to the second glaciation, which is termed the Kansan. Deposition of gravel in some of the principal streams and of wind-blown silt on the uplands was taking place outside of the glaciated area during this period.

The point nearest to the two counties concerned in this report that was reached by the ice of Pleistocene time is the valley of the Little Blue and its tributaries in Washington county. Here, according to Todd,[1] a glacial lake, called Lake Washington, was formed by the damming of the waters of eastward-flowing streams by the ice. The principal evidence for this lake, as interpreted by Todd, is the line of glacial bowlders rafted by floating ice and deposited along the edges of the lake. The bowlders are found at an elevation of 1,400 feet, and so it is possible that bowlders and gravels of this origin may be found in the bottom of Mill and other creeks

1. Todd, J. E.: Report on the Glacial Geology of Kansas; unpublished manuscript in the office of the State Geological Survey.

northeast of Cuba, where for a short distance the elevation is below 1,400 feet.

LOESS. Much of the upland in western Kansas is underlaid by a fine, uniform-grained material that has been referred to as "plains loess."[2] It is found over a large part of Cloud and Republic counties and ranges in depth from a few inches to 30 or 40 feet. Excellent exposures may be seen on the bluffs south of Republican river and in many of the road cuts in the area. Plains loess consists of dust-like material that has been derived from weathering of older formations. It is composed of clay particles, extremely fine sand

PLATE VII.—Loess exposed in road cut at the southwest corner of sec. 13, T. 1 S., R. 5 W., Republic county.

grains and some calcareous and organic materials. When dry it is a light gray to light buff in color. It shows no bedding and is eroded into vertical columns where exposed along the face of a bluff. Small irregular calcareous concretions are found in it locally. Although it is easily pulverized, so that roads through it are extremely dusty during the dry season, it has the surprising property of standing in vertical cliff faces. It weathers to a loamy soil, making the best uplands soil in Cloud and Republic counties.

Plains loess is primarily Pleistocene in age. It is still being formed, however, as can be seen from the clouds of dust that rise from the newly plowed fields on a windy day, and the dust deposits formed by windstorms.

GRAVEL AND SAND. Gravel and sand of Pleistocene age occur in areas north of Solomon river between Glasco and Simpson, south-

2. Darton, N. H.: The Geology and Underground Water Resources of the Central Great Plains; U. S. Geol. Survey, Prof. Paper 32, p. 155, pl. 44; 1905.

east of Glasco, and along the south bluff of the river in the same vicinity. The deposit north of the river near Simpson covers an area of several square miles and lies at an elevation of approximately 1,400 feet, while those to the southeast are 50 to 60 feet lower. The deposits are more or less continuous and not more than 30 feet in thickness.

The gravel varies in structure and coarseness even in one pit, yet the description of one serves to show the general character of the deposit as a whole. The gravel in the Chris Weaver pit in the northwestern quarter of sec. 32, T. 7 S., R. 5 W., has a thickness of 14 to 16 feet. The material ranges in size from fine sand to pebbles an inch in diameter (see analysis). Approximately one-tenth of the

PLATE VIII.—Chris Weaver sand and gravel pit in the NW¼, sec. 32, T. 7 S., R. 5 W., Cloud county.

material is retained on the ¼-inch screen while at least 50 per cent may be classed as medium to fine sand. The finer material is composed largely of quartz which is moderately well rounded, while the larger pebbles are nearly flat and are composed mostly of fragments of the near-by outcropping beds of Cretaceous (Lincoln and Jetmore) limestones. Some of the unusual features are (1) fragments of calcite from septaria of the Carlile shale which crops out many miles to the west, (2) shark teeth and reptile vertebræ that have weathered from the Jetmore limestone beds, and (3) bones of mammals that lived during the Pleistocene. The deposit is rudely stratified and cross-bedded with the cross-laminæ dipping toward the south and southeast. At the base of the deposit are masses of clay 1 to 2 feet in diameter. While the sand and gravel are, in general, loosely consolidated, in some places the deposit is firmly cemented by calcium carbonate.

The gravel deposits found south of Solomon river occur on the Hugh Beck farm, 4 miles southwest of Glasco, and on the Walter

Butler farm, 4 miles south of Glasco. The latter is thicker and more extensive and contains much less clay. Both deposits lie at an elevation of 1,340 feet, which is the same as the lowest part of the deposit north of the river. The material ranges in size from fine clay and sand to bowlders a foot or more in diameter. The finer sand and gravel is composed primarily of quartz and limestone while the larger pebbles and bowlders are limestone fragments from the Lincoln and Jetmore beds, and ferruginous nodules from the Dakota sandstone in which the ancient valley was cut. The large

PLATE IX.—Texture of gravel at the face in the Walter Butler pit in sec. 2, T. 9 S., R. 5 W., Ottawa county, south of Glasco.

percentage of calcite in the finer material is due to the presence of internal casts of shells of one-celled animals called Foraminifera, which were weathered from the older Cretaceous formations and washed into the sand. Two genera, *Globigerina* and *Gümbelina,* are present. These fossils are both interesting because of their shape and excellent preservation, and important because they are the source of calcite which cements the sand in all of the pits of this region.

The age of the sand and gravel deposits was determined by the aid of other fossils which were indigenous. An excellently preserved lower jaw bone of a horse was found deep in the sand of the Chris Weaver pit by Lesley Teasley, of Asherville, and donated to the State Geological Survey. It is judged from the size of the bone that the horse must have been as large or larger than the modern draft horse, while the teeth are almost as complicated. The specimen is similar to the teeth and jaw of *Equus complicatus* Leidy of Pleistocene age. Consequently the deposits have been classified as Pleistocene and are probably equivalent to similar beds found in Russell and Ellis counties[3] to the west and in McPherson county to the southeast.[4]

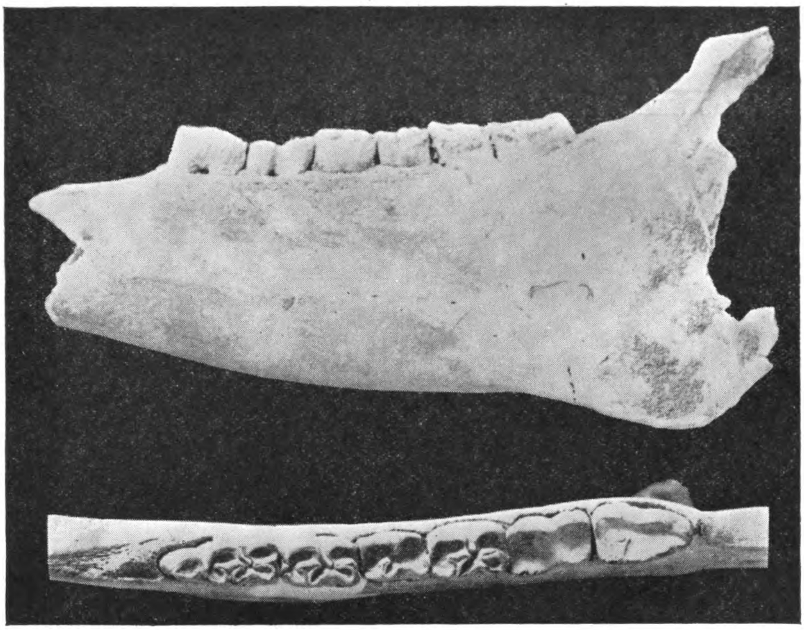

PLATE X.—Side and top views of lower jaw bone of a horse (*Equus complicatus* Leidy) taken from the Chris Weaver sand and gravel pit near Glasco, Cloud county. About one-third natural size.

From the character and structure of the deposits it is clear that they were formed by the early Solomon river. Since their deposition, the river has not only largely removed a fill of 40 or 50 feet of sand and gravel in the valley, but has eroded the channel to a total depth of 60 to 70 feet.

3. Rubey, W. W., and Bass, N. W.: The Geology of Russell County, Kansas; State Geol. Survey of Kansas, Bull. 10, p. 19.

4. Haworth, Erasmus: The McPherson Equus Beds; University Geological Survey of Kansas, vol. II, pp. 285-295; 1896.

Tertiary.

Belleville Formation.

Thick deposits of gravel, sand and clay were formed in the Great Plains during the Tertiary period by streams which rose in the Rocky Mountains and flowed eastward. A deposit of this kind, described here for the first time and named the Belleville formation, occurs in the northern half of Republic county. The most prominent feature of this formation is that it occupies a broad but well-defined channel approximately 200 feet deep extending from near White Rock, at the western edge of Republic county, to Chester, Neb. It also extends beyond the old channel onto the uplands, where it has a thickness ranging from 40 to 80 feet. North of Belleville the base of the formation rests on an almost flat surface of Carlile shale which slopes gently northward toward the old channel. Farther east the deposit is slightly lower and is in contact in places with the "fence post" limestone. The surface on which the deposit rests has an elevation ranging from approximately 1,600 feet on the uplands near Belleville to about 1,400 feet in the old channel near Chester. The channel itself is nearly 100 feet lower near Chester than at Republic City, showing that the stream flowed eastward.

The limits of the Belleville formation are in some places difficult to determine, since sand and clay derived from it have been washed down the slopes. Near Belleville, however, the basal gravel of the formation is exposed where small streams have cut back into it. The Swierzinsky, McCullough and Hanslick gravel pits, northwest of Belleville, and the Hinal, Keperta, Wocal and Shimek sand and gravel pits, north of Cuba, are near the edge of the deposit. At a great many places along the creeks water seeping from the gravel at the contact with the underlying shale clearly defines the edge of the deposit.

The lithologic character of the formation was studied by an examination of the gravel and sand pits and through the records of water wells. While the formation differs a great deal from place to place, it consists primarily of clay or sandy clay in the upper one-half and sand or gravel in the lower part. Almost every well log shows thin lenses of sand or gravel in the clay and many of the wells pass through a bed or two of clay in the lower gravel. The lowermost few feet of clay in many of the wells are highly calcareous, white, and more or less compact. The clay is listed by the drillers as "magnesia rock." Lenses of this material are not uncommon, however, in other parts of the section, even in the lower gravel beds. The basal part of the formation, as shown in the pits, consists of quartz and feldspar ranging from very fine fragments to pebbles ¼ inch in size. Most of the material passes through a 10-

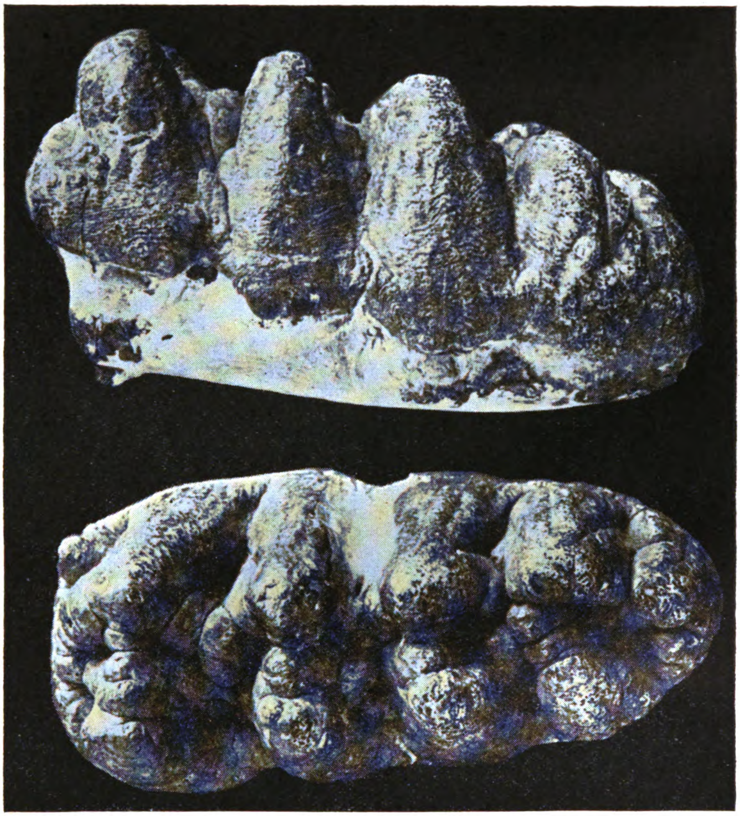

PLATE XI.—Side and top views of tooth of trilophodon or bunomastodon, one of the long-jawed Proboscidia, taken from the McCullough sand pit northwest of Belleville. One-half natural size.

mesh screen but is retained on the 20-mesh. The quartz grains are moderately well rounded. The feldspar tends to be more rectangular and is gray to pink in color. Occasional pebbles of granite up to an inch in diameter, containing primarily quartz and feldspar, indicate the source of these two minerals. The original source of the granite was the Rocky Mountains.

The stream in which the Belleville formation was deposited flowed from the west. It was comparable in size to Republican river and followed approximately the present course of this river as far east as Republic City. From this point, however, the stream continued toward the north and east instead of turning south as does the Republican. As far as can be determined only one formation fills the channel, although this cannot be determined with certainty. It is clearly of Tertiary age and probably equivalent to a part of the Ogalalla formation[5] of western Kansas, but because of great distance the correlation is made provisionally.

A number of fossils have been found in the sand and gravel pits mentioned. Unfortunately, however, most of these have been destroyed or permitted to disintegrate by persons who did not realize their importance in determining the age of the beds. Middle Pliocene age is indicated by the identification of teeth of trilophodon,[6] a bunomastodon or long-jawed Proboscidean represented among living forms by the elephant. Two teeth were taken from the McCullough pit, of which one was donated to the State Geological Survey by Mr. McCullough and the other loaned for purposes of identification by Dr. W. R. Barnard, of Belleville.

Cretaceous.

The Cretaceous contains the only marine beds exposed at the surface in Cloud and Republic counties. Reference to the following table shows that four formations are represented—a lower sandstone famous as a water-bearing formation, an intermediate shale, a limestone member, and an upper shale division.

Cretaceous formations in Cloud and Republic counties.

Carlile shale	Undifferentiated.
Greenhorn limestone	Pfeifer shale.
	Jetmore limestone.
	Lower Greenhorn shale.
Graneros shale	One member.
Dakota sandstone	Five members.

Carlile Shale.

The Carlile shale is the uppermost Cretaceous formation exposed in Cloud and Republic counties. Because of its topographic position and its argillaceous character it has been removed by erosion to

5. Darton, N. H.: The Geology and Underground Water Resources of the Central Great Plains; U. S. Geol. Survey, Prof. Paper 32, p. 178; 1905.

6. Identification by H. T. Martin and Dr. H. H. Lane, of the University of Kansas.

such an extent that only a thin and badly weathered layer is present capping the uplands. It is so covered with slopewash that relatively few exposures may be seen. The Carlile shale is the "blue slate" encountered by drillers beneath the Tertiary water gravels in Republic county. Where some of the streams have cut back into the gravel, a few feet of the underlying and basal part of the Carlile is exposed.

The total thickness of the Carlile is approximately 280 feet. To the southwest it has been divided into a lower calcareous phase called the Fairport[7] member and an upper noncalcareous part named the Blue Hills[8] shale member. Although these divisions can be recognized in Republic county the contact between them is not sharp, and consequently the Carlile is not subdivided in this report. While the total thickness is the same as that given for the Carlile in Russell and Ellis counties,[9] the lower calcareous phase is much thicker in Republic county. It is impossible from the scattered sections taken to give a complete detailed section of the Carlile in Cloud and Republic counties, but the following partial sections show the character of the lower and middle parts of the formation:

Section of the lower part of the Carlile shale near the southeast corner of sec. 20, T. 12 S., R. 2 W., Republic county.

	Ft.	In.
Carlile shale:		
11. Limestone, reddish-buff at top	..	5
10. Shale, blue gray; calcareous. Contains numerous *Ostrea* shells	5	..
9. Limestone, dark buff. Varies greatly in thickness. Splits into thin layers	..	3-7
8. Shale, light gray. Calcareous	6	..
7. Limestone. Splits into three distinct layers. The two upper layers are separated by an ochre-red seam of clay along which the limestone is reddish-buff in color. Middle layer is more compact than the other two and is slightly banded. Lowermost layer is chalky and weathers rapidly	..	8-9
6. Shale, gray. Calcareous	2	10
5. Limestone, gray. Intermediate ¼-inch is cross laminated	..	1
4. Shale, gray. Calcareous	2	6
3. Limestone. Lower part light buff; upper reddish-buff	..	3½-4
2. Shale, calcareous	..	2
Greenhorn limestone—Pfeifer shale member:		
1. "Fence post" limestone	..	9

7. Rubey, W. W., and Bass, N. W.: The Geology of Russell county, Kansas; State Geol. Survey of Kansas, Bull. 10, p. 40.

8. Logan, W. N.: The Upper Cretaceous of Kansas; The University Geological Survey of Kansas, vol. 2, pp. 218, 219, 225; 1896.

9. Rubey, W. W., and Bass, N. W.: The Geology of Russell county, Kansas; State Geol. Survey of Kansas, Bull 10. Bass, N. W.: Geology of Ellis county; State Geol. Survey of Kansas, Bull. 11.

Section of the middle part of the Carlile shale exposed along bluff in the SW¼ of sec. 2, T. 2 S., R. 5 W., Republic county.

	Ft.	In.
14. Clay, sand and gravel belonging to the Tertiary	10-12	..
13. Shale, blue-gray. Contains lemon-yellow flakes and fragments of large-shelled *Inoceramus*	23	..
12. Bentonite, thin white	..	½
11. Shale, blue-gray. Contains numerous fragments of large-shelled *Inoceramus*	10	..
10. Clay, brown, containing thin flakes and small crystals of gypsum. Has bentonitic seam at center	..	2
9. Shale, blue	5	..
8. Gray limestone bed containing many small shells of *Inoceramus*. At the top of this is a zone containing small brownish concretions 1 to 4 inches in diameter	..	4
7. Shale, blue	..	5
6. Clay, similar to No. 10	..	3
5. Shale, blue papery; containing numerous fragments of large *Inoceramus* shell and *Ostrea*	2	..
4. Clay, similar to No. 10	..	3
3. Shale, blue	4	..
2. Clay, brownish	..	1
1. Shale, blue, papery; contains numerous *Ostrea* shells	12	..

The upper 100 feet of the Carlile is not exposed in Cloud or Republic counties, but may be seen under the protecting edge of the Fort Hays limestone in the bluff across the line in Jewell county, a mile southwest of White Rock. Here it consists of papery, noncalcareous shale of light to dark blue-gray color. No fossils were observed in the shale in this locality, and there are only a few of the septarian concretions that are so prominent in this formation elsewhere.

The lower part of the Carlile is lighter in color than the upper. In its unweathered condition it is the same blue-gray, but where weathered it varies from yellow to buff. It contains numerous shells of *Ostrea,* fragments of a thick-shelled *Inoceramus* and casts of borings of the worm *Serpula.* In addition there are brownish fish scales and imprints of the coiled cephalopod *Prionotropis woolgari.*[10] Because of the large number of *Ostrea* shells this lower division was first referred to by Logan[11] as the "*Ostrea horizon.*"

As may be seen in the section, there are a number of thin limestones in the lower part of the formation. The most prominent one occurs 17 feet above the "fence post" limestone and is approximately 5 inches thick. It varies in color from a light buff at the

10. Identification by J. B. Reeside, Jr., of the United States Geological Survey.

11. Logan, W. N.: The Upper Cretaceous of Kansas; The University Geological Survey of Kansas, vol. 2, pp. 218, 219, 225; 1896.

base to a reddish-buff at the top and so may be confused, especially when weathered, with the "fence post" limestone. The lower shale contains also thin but remarkably persistent bentonite clay, a substance that has been ascribed to the weathering of volcanic ash. Some of these layers appear to be unweathered and are white in color, but most are rusty brown. They are characterized by a texture as fine as that of clay, and by a lack of horizontal stratification. Fragments of the material crumble easily into many-sided, very irregular particles. Soil derived from bentonite clay has a peculiar salmon-brown color.

Greenhorn Limestone.

The most prominent formation in both Cloud and Republic counties is the Greenhorn limestone. Because the resistance of the limestones in this formation is much greater than that of either the Carlile shale above or the Graneros shale below the Greenhorn is found outcropping along the brow and on the steep slopes of the hills. This formation is readily recognizable, for it contains the only limestones outcropping in either Cloud or Republic county. These white-layered rocks can be seen around the edges of the hills and in many road cuts. Some of the Greenhorn limestones have been extensively quarried and used for fence posts, flagging and building purposes. The top of the formation is the top of the "fence post" limestone and the bottom is the base of the lowest (Lincoln) limestone bed.

In some of the more recent work in western Kansas the Greenhorn has been subdivided into four members,[12] but in Cloud and Republic counties only the upper two are recognized while the lower two are undifferentiated.

Members of the Greenhorn limestone with characteristics and thickness.

	Ft.
Pfeifer shale:	
"Fence post" limestone bed and underlying gray calcareous shale....	15-16
Jetmore limestone:	
"Shell rock" at top and thin limestone beds below, alternating with gray calcareous shale........	13-14
Lower Greenhorn undifferentiated:	
Blue-gray, calcareous shale containing thin crystalline limestones, numerous bentonite-clay layers, and a crystalline limestone bed at the base	45-53

12. Rubey, W. W., and Bass, N. W.: The Geology of Russell county, Kansas; State Geol. Survey of Kansas, Bull. 10, p. 45.

Pfeifer Shale Member.[13] The Pfeifer shale member consists largely of yellowish-gray, calcareous shale, although it contains, also, a number of thin limestones in its lower and middle parts and the well-known "fence post" limestone at the top. With the exception of the "fence post" limestone the member is not resistant to erosion and consequently has been worn back from the face of the bluff where it outcrops above the Jetmore. The best exposures are seen along some of the creeks where surface wash and loess have been removed.

Plate XII.—"Fence post" limestone bed exposed in creek near the southwest corner of sec. 6, T. 3 S., R. 1 W., Republic county.

The "fence post" limestone is the most resistant bed in the member as well as the most distinctive in color and texture. It is light cream-buff in color at the top and bottom, grading toward the center into a much darker band of buff. It is chalky in texture, soft enough to be cut when freshly quarried, but hardens considerably on exposure. It varies in thickness from 6 to 9 inches. Numerous fossils have been found in it, including vertebræ of reptiles and fishes, and among invertebrates imprints of the coiled-shelled cephalopod *Prionotropis woolgari* and shells of a small pelecypod belonging to the genus *Inoceramus*. The last-named have a higher, more rounded beak and different surface markings from the *Inoceramus labiatus*. The "fence post" rock has been quarried extensively in the area and used in building fences, bridges and buildings.

13. Bass, N. W.: Geology of Ellis County; State Geol. Survey of Kansas, Bull. 11, p. 32.

There is a 1- to 2-inch limestone bed just below the "fence post" limestone in Cloud county, but this is less prominent in Republic county than a 3- to 4-inch light buff limestone which occurs 2 inches above. A distinguishing mark is the remarkably persistent 1-inch seam of gray bentonite-clay 5 to 6 inches below the "fence post" bed. Two remarkably persistent limestone beds 2 to 3 inches thick occur 3½ and 4½ feet below the "fence post" limestone. Both are alike in containing thinly laminated layers and in having a background of light cream-buff color with irregular patches of blue-gray. In the lower part of the Pfeifer shale member are many thin layers

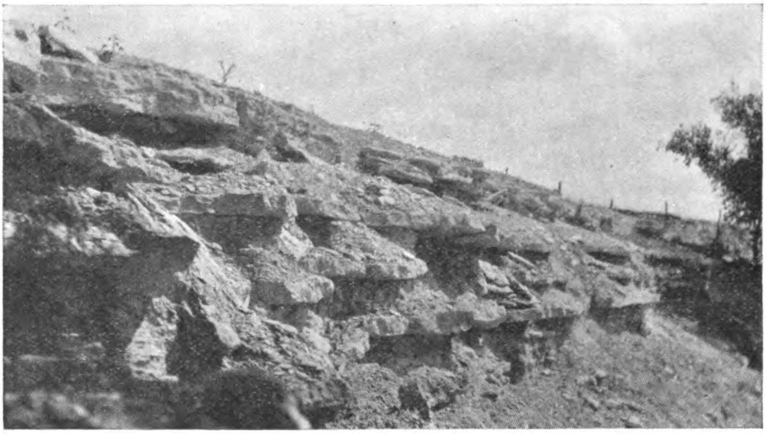

PLATE XIII.—Uppermost limestone beds of the Jetmore, including the "shell rock" at the top. South side of highway U. S. 36 two and one-half miles east of Belleville, Republic county.

of limestone which tend to vary in thickness and are discontinuous. These weather into discoidal concretions containing shells of a large but thin-shelled *Inoceramus*. The more persistent beds are found 14, 28, 36, 60, 70, 80 and 90 inches above the base of the formation.

The Pfeifer shale in this area differs from its exposures in Russell and Ellis counties. The succession of thin beds is not the same and the total thickness is 3 or 4 feet less. In general, however, the member shows the same characteristics and can easily be identified from descriptions given for outcrops, not only in Russell and Ellis counties but as far west as Colorado.

JETMORE LIMESTONE MEMBER.[14] The Jetmore is the principal

14. Rubey, W. W., and Bass, N. W: The Geology of Russell county, Kansas; State Geol. Survey of Kansas, Bull. 10, p. 51.

limestone member of the Greenhorn. It consists of the prominent "shell rock" at the top and 12 or 13 thin limestone beds below, alternating with blue or gray calcareous shale. The "shell rock" is approximately 12 inches thick and is characterized principally by the fact that it is the thickest bed of the series. It varies in texture from chalky to finely crystalline, is white or light gray in color, and contains numerous shells of the pelecypod, *Inoceramus labiatus*. It is difficult to distinguish between the various thin beds of limestone in the lower part of the member except where they are found in place below the "shell rock." In general, however, shells of *Inoceramus* are more abundant in the upper part of the member, although they are common in the entire section. Other fossils found are large, coiled cephalopods 5 or 6 inches in diameter, and shark teeth. The latter can be found in relatively great numbers on any weathered slope of the member, particularly after a heavy rain has removed the protecting clay.

Numerous sections of the Jetmore can be seen in both Cloud and Republic counties, and they show remarkable persistency of even the thinner beds. A single section, therefore, will be sufficient to show the character of the member over the entire area.

Section of Jetmore chalk member taken from the center of the south side of sec. 16, T. 6 S., R. 3 W. in road cut on U. S. highway No. 81.

	Ft.	In.
26. Limestone, fine-grained; gray to light buff; massive, very fossiliferous	..	10
25. Shale, thinly laminated; calcareous; light to gray in color; contains many thin limestone beds	2	6
24. Limestone, very fossiliferous; gray; fine-grained; compact	..	3
23. Shale; thinly laminated; chalky	1	..
22. Limestone, fine-grained; whitish-gray; compact; fossiliferous	..	4½
21. Shale, thinly laminated; light gray to buff; chalky	..	9
20. Limestone, light gray; compact; fossiliferous (Ammonite shell)	..	4½
19. Shale, light gray to buff; thinly laminated; calcareous	1	3
18. Limestone, very compact; brown streak in center, light gray	..	2½
17. Shale, light gray to buff	..	5
16. Limestone, buff streak and limonite concretions in center	..	2½
15. Shale, thinly laminated gray to buff; lower 2 inches dark buff	..	7
14. Limestone, chalky; gray	..	3
13. Shale, thinly laminated; gray	..	2½
12. Limestone, fine-grained; white	..	4½
11. Shale, thin; light buff	..	6
10. Limestone, fine-grained; gray	..	2½
9. Shale, thin; buff-colored	..	5
8. Limestone, fine grain; light gray to buff	..	2
7. Shale, light gray to buff	..	5

	Ft.	In.
6. Limestone, compact; light gray	..	2½
5. Shale, gray, buff, and tan-colored	..	5
4. Limestone, fine grain, compact	..	2
3. Shale, light buff and tan, gray	..	6
2. Limestone, very compact; rust-colored, limonite concretions in center	..	3
1. Lower Greenhorn shale	17	..

The "shell rock" and other beds of the member have been quarried extensively in Cloud county and in a few places in Republic county. In these places the more desirable "fence post" limestone is absent and the "shell rock," particularly, is used as a substitute in building fences and for other purposes.

Lower Greenhorn Shale. The lower part of the Greenhorn limestone consists of calcareous shale containing a moderately prominent limestone at the base and a number of thin crystalline limestones at various places in the section. The total thickness is from 45 to 50 feet. The lower Greenhorn is divided into the Lincoln and Hartland members in the counties to the west. The contact between the Hartland and Lincoln cannot be recognized in either Cloud or Republic county, and because of the similarity of the section from bottom to top they are not separated in this report. Crystalline limestones which are confined to the Lincoln member in Ellis and Russell counties are found within 5 feet of the base of the Jetmore in Cloud and Republic counties. Others occur at distances of 12, 15, 20 and 28 feet below the overlying limestone member, while a slightly more prominent layer occurs at the base of the formation. This lowermost bed was termed the "Lincoln marble" by Cragin,[15] but as it is not a true marble it will be referred to as the Lincoln limestone bed in this report. The Lincoln limestone bed is coarsely crystalline, blue-gray when fresh and brownish when weathered. It breaks into very irregular slabs and emits a strong petroleum odor when freshly fractured.

An unusual bed occurs beneath the Lincoln limestone in secs. 22 and 27, T. 2 S., R. 1 W., north of Cuba in Republic county. It consists of a layer of transversely crystalline calcite from 3 to 6 inches thick, which in some places is in contact with the base of the limestone and in others is separated from it by 3 or 4 inches of sandy clay. The calcite has a radiating habit which gives the rock the appearance of cone-in-cone structure. Extending through the center of the bed is a very irregular stylolite seam. Although this

15. Cragin, F. W.: On the Stratigraphy of the Platte Series or Upper Cretaceous of the Plains; Colo. College Studies, vol. 6, p. 50; 1896.

layer is moderately thick it is extremely local and is not found beneath the Lincoln limestone in other parts of Cloud and Republic counties.

The thin crystalline limestone beds near the middle and top of the lower Greenhorn shale are white, gray or blue in color, and range in thickness from a small fraction of an inch to 2 inches. Often a number of beds occur together in a thin zone. They are not as coarse in their texture as the Lincoln limestone bed, but emit the same petroleum odor when broken. In addition to limestone the lower Greenhorn contains many thin layers of bentonitic clay, which differ from the shale in being finer grained, buff in color and not laminated. The bentonite contains no grit and is structureless. Its origin has been ascribed to the weathering of volcanic ash.

The following section shows the nature of the member in this region:

Section of the lower Greenhorn in NE¼ sec. 28, T. 7 S., R. 3 W.

	Ft.	In.
49. Pfeifer shale member	15	..
48. Jetmore limestone member	13	..
Lower Greenhorn.		
47. Shale, flaky; calcareous; zone 18 inches below the top more calcareous and more resistant	5	..
46. Bentonite; weathers brown; crumbly	..	6
45. Clay, chalky; light gray to buff; not laminated. Contains thin seams of crystalline limestone	..	3
44. Shale, calcareous; light gray; brown seam 5 inches from bottom; flaky	1	4
43. Clay, bentonite; plastic; dark buff, and blue-gray	..	5
42. Limestone, light buff; seam 1 inch below top	..	2½
41. Clay, bentonite; light to buff	..	3
40. Clay, bentonite; dark buff and blue-gray	..	5
39. Shale, poorly exposed	..	5½
38. Limestone, crystalline; irregular in thickness; crystalline part blue-gray, remainder chalky; contains bits of shell	..	2
37. Shale, calcareous; contains thin seams of limestone and broken bits of shells similar to bed above; grades laterally into blue and buff layered clay	1	..
36. Clay, blue and buff; thin seams of crystalline limestone and bentonite	1	6
35. Shale, laminated; gray to buff	..	2
34. Clay, bentonite	..	½
33. Shale, blue and brown; layered; many bentonite seams; some slightly calcareous; contains fossils	3	2
32. Clay, bentonite	..	1
31. Shale, thin layered; calcareous	..	4
30. Clay, bentonite; brown and blue	..	4½
29. Shale, calcareous; thin layered; fossils	..	10
28. Bentonite, clay; dark buff and blue	..	3½

Duplicated in part and continued in southwest corner NW¼ sec. 22, T. 6 S., R. 5 W.

27.	Shale, flaky; contains several thin bentonite seams	2	..
26.	Limestone, thin crystalline	..	2
25.	Bentonite, buff	..	2
24.	Shale, flaky; contains several blue-gray and brown bentonite seams and thin crystalline limestone bed	4	2
23.	Bentonite	..	3½
22.	Shale, gray	..	3½
21.	Bentonite	..	3
20.	Shale, gray; several thin crystalline limestones in top and bottom	..	11
19.	Bentonite	..	2
18.	Shale, gray; calcareous	2	7
17.	Bentonite	..	1
16.	Shale, gray; calcareous	..	3
15.	Limestone crystalline; petroleum odor	..	2

Continued in southeast corner SW¼, sec. 6, T. 4 S., R. 2 W.

14.	Clay, bentonite; yellow where weathered	..	6
13.	Shale, thin crystalline limestone beds at top	1	..
12.	Limestone, banded gray and tan; finely crystalline; discontinuous	..	5
11.	Shale, tan and gray	1	3
10.	Limestone, very hard; coarsely crystalline; blue-brown; very petroliferous; nonfossiliferous	..	2
9.	Shale, tan with gray zones	..	11
8.	Limestone, dark brown	..	¼
7.	Shale, gray and yellow	..	11
6.	Limestone, gray-brown; fine; nonfossiliferous	..	1
5.	Shale, yellow brown	..	9
4.	Limestone, dark brown; crystalline; less coarse and less fossiliferous than basal bed	..	3
3.	Bentonite clay, white and yellow	1	2
2.	Shale, dark gray	..	1
1.	Limestone, dark brown; coarsely crystalline; very fossiliferous. (Lincoln limestone bed of this report)	..	3

Graneros shale:

GRANEROS SHALE.

The Graneros shale lies between the Greenhorn limestone and the Dakota formation. Its upper contact is moderately distinct since its shales differ from those above in not being calcareous, and the Lincoln limestone bed lies at the base of the Greenhorn. The lower contact, however, is more difficult to determine, due to the fact that the sandstones in the upper part of the Dakota are massive in some places and thin-bedded and shaly in others. Where the former condition exists the contact is placed at the top of the sandstone.

In places where the sandstone is absent the contact is recognized by a change from dark-colored shale containing small flakes of gypsum to sandy powder-blue shale below.

The Graneros shale is a noncalcareous clay shale varying in color from dark blue to black. It contains numerous lemon-yellow flakes of sandstone and transparent crystals of gypsum. In some places there is a bed of brown sandstone near the center and thinner rusty-colored lenses both above and below. The shale weathers to a heavy clay which shows numerous desiccation cracks during the dry season. The formation thins to the north and east. It has a thickness of 60 feet in Hamilton county, 40 feet in Russell county and 30 to 20 feet in Cloud and Republic counties. In its general characteristics, however, the formation is the same in all three localities.

Dakota Formation.

Nearly 400 feet of the Dakota formation outcrops in Cloud and Republic counties. This consists of sandstone and shale, the relative proportions being nearly equal but varying from place to place. In general three sandstones can be recognized which, with the intervening shales, constitute five divisions in all. The lowest sandstone crops out in the extreme southeastern corner of Cloud county, where its maximum thickness is approximately 100 feet. Its upper few feet may be seen in the creeks near Miltonvale, while almost its entire thickness is exposed in the creek valley three miles south and a mile east. The following section shows the character of this member.

Section of the lower sandstone member of the Dakota formation center of SW¼, sec. 34, T. 8 S., R. 1 W.

		Feet.
5.	Sandstone, medium coarse, dark brown, resistant; caps hills in this region	10
4.	Sandstone, fine-grained, buff color, friable	30
3.	Sandstone, dark brown, medium coarse; cross-bedded; causes distinct bench	5
2.	Sandstone, fine-grained, massive; some of beds cross-bedded	40
1.	Sandstone, very fine-grained; cross-bedded	24

The next overlying member is composed of mottled clay shale. It is approximately 100 feet thick and is overlaid in turn by the 20- to 40-foot intermediate sandstone. The latter outcrops at the top of the hills two miles northeast of Miltonvale. The character of these two members is indicated by the following section:

Sections of parts of the lower shale and intermediate sandstone members of the Dakota formation.

Section 1. Center of NE¼, sec. 19, T. 8 S., R. 1 W. (200 yards south of Miltonvale station).

	Feet.
3. Sandstone; coarse-grained, brown; cross-bedded with laminæ dipping toward south and west	3
2. Shale, clayey, light-colored; light gray, mottled with buff, chocolate red and lavendar colors; contains thin seams of rust-colored sandstone and lenses of massive fine-grained sandstone. (Basal part of lower shale)	34
1. Sandstone. (Upper part of lowest sandstone member.) Lower part fine-grained and more or less massive; light buff. Upper part coarser and redder; contains numerous clay-pebble concretions which leave surface pitted	16

Section 2. Southwest corner NW¼, sec. 11, T. 8 S., R. 1 W.

4. Sandstone, coarse-grained, dark brown in color; very resistant; causes hills to be flat-topped with sharp edges and steep slope below. (Lower part of middle sandstone member)	8-10
3. Shale, clayey, mottled red, light gray and chocolate color. (Upper part of lower shale member)	45
2. Sandstone, gray: Very hard	2
1. Mottled clay shale similar to that above	10

Section 3. Northwest corner SW¼, sec. 22, T. 7 S., R. 1 W: South side of creek.

2. Sandstone, medium coarse. (Lower part of middle sandstone member.) Ochre-yellow to dark brown; individual beds 6 inches to 2 feet thick; cross-bedded; lamina average an inch in thickness and dip five degrees to 30 degrees toward the south, southeast and southwest; cross-bedding sharply defined in upper part, indistinct in lower; contains much coarser sand in lower part; top portion of individual beds a conglomerate in which the pebbles are composed of gray clay balls averaging ½ inch in diameter. As these weather out the surface becomes pitted and very rough. Sandstone also contains numerous concretions of different composition. These have been separated into the following:
   1. Mud centers.
   2. Sandstone.
   3. Ironstone.
   4. Sand centers same as (1) except that sand fills the cavity.... 8-10
1. Clay-shale, measured from edge of water in creek. Light green, gray, buff and chocolate red; contains fine sand near base but coarse near top. Numerous small concretions resembling worm borings.......... 24

PLATE XIV.—Cross-bedded Dakota sandstone occurring east of the southwest corner of sec. 25, T. 7 S., R. 1 W., Cloud county.

The upper shale member is similar to the lower in texture and color. It ranges in thickness from 80 to 100 feet and is overlaid by the upper sandstone member, which is 40 to 80 feet thick. The latter outcrops on the hills southwest of Glasco, on the higher hills between Glasco and Miltonvale and on the bluff south of the river near Concordia. Other prominent outcrops occur on the higher knolls in the southeastern part of Republic county. The following section shows the character of the two upper members:

Section of the two upper members of the Dakota formation, southeast corner sec. 27, T. 8 S., R. 5 W.

	Feet.
2. Sandstone on top of hill; ochre-yellow, red brown, or black; fine to medium-grained; ferruginous; contains numerous concretions and gnarled layers; some of cross-bedding. Beds at 10, 60 and 85 feet above base cause knobs or rough sandstone knolls................	80-85
1. Shale; argillaceous; massive; variegated light gray, blue-gray, reddish-purple, red. Small grains of hematite cause red spots. Basal portion grades by long gentle slopes into flood plains.............	55

As stated previously, the top of the Dakota formation consists in places of shale containing thin lenses of sandstone, but this is not sufficiently persistent to constitute a sixth member.

While the various members of the Dakota thicken and thin, and the shale in some places contains lenses of sandstone and the sandstone layers of shale, the five members outlined are sufficiently prominent to be identified readily in the field. As may be seen in figure 2 these divisions can be recognized also in the logs of wells drilled in Cloud and Republic counties, although there is a tendency

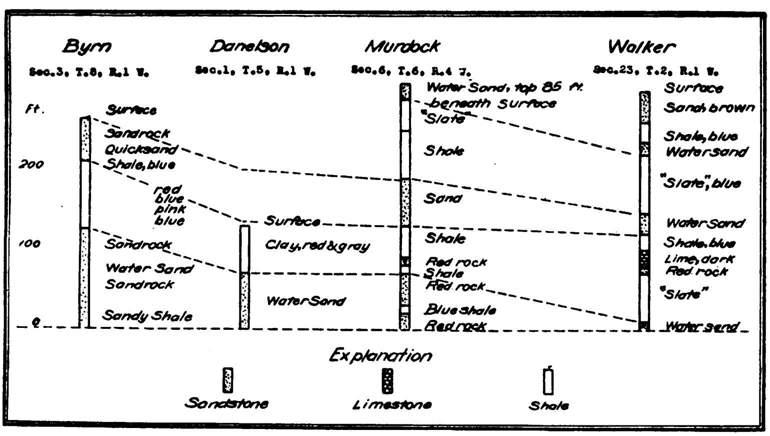

FIG. 2.—Graphic presentation of the Dakota formation as shown in well logs.

for the lowest sandstone member to thin to the north. The five-fold development of the Dakota in Cloud and Republic counties resembles many of the sections of the same formation in Colorado, while if the relatively thin intermediate sandstone is ignored the upper and lower sandstones separated by shale resemble the Dakota, Fuson and Lakota of the Black Hills.

Many of the characteristics of the different Dakota members are sufficiently general to apply to the entire formation. The shale is argillaceous and mottled. It contains salt and gypsum, which have aided in the disintegration of the rock and have caused salt marshes in some of the creeks tributary to Republican river. The sandstone is commonly brown and contains varying quantities of iron cement, which results in many curiously shaped, gnarled and twisted forms. Concretions are common, although not confined to any particular horizon. At least four types are recognizable as follows: (1) Pyrite concretions found in the shale, (2) masses or balls of sandstone cemented with iron oxide, (3) Ferruginous shells filled with loose sand, and (4) concretions similar to the last-described but containing a filling of gray-colored clay.

Black lignite has been reported from various horizons in the Dakota. The only bed observed in Cloud and Republic counties is the one mined near Minersville between Belleville and Concordia. Here the coal is approximately 2 feet thick and is divided slightly above the center by a seam of "black jack" or impure coal. It occurs 12 feet below the top of the upper sandstone member of the Dakota.

The Dakota has been used to a slight extent as a building stone, although its lack of uniformity in color, texture and structure prevent its extensive use in this way. Many of the wells in the region obtain water from one of the Dakota sandstone beds. Although the Dakota has been an important source and much of the water is of excellent quality, in certain areas it contains salt, gypsum and iron and is not suitable for domestic use.

The Dakota formation shows a greater diversity in its surface features than any other formation exposed in Cloud or Republic counties. In eastern Cloud county and along most of Republican river east of Concordia the Dakota country is gently rolling. The same is true of much of the region north and east of Glasco. In relatively small areas, however, such as those already mentioned near Miltonvale, at the twin mounds 10 miles southeast of Concordia, and in a few places east of Talmo, there are relatively high

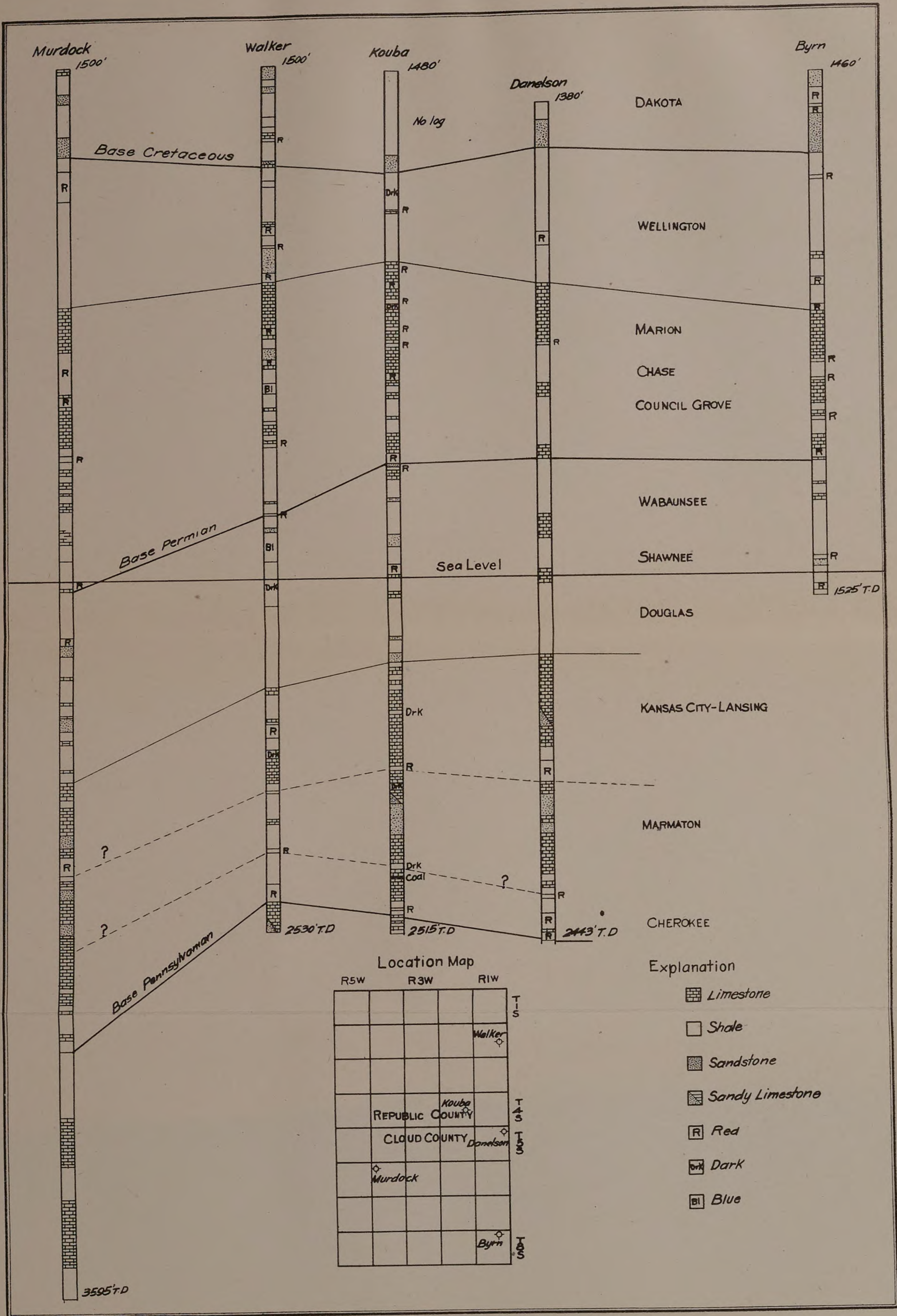

Plate XV.—Graphic correlation of well logs.

ridges and knolls capped by rough brown sandstone. The slopes are steep and strewn with sandstone bowlders, while the soil is thin and the land used principally for grazing.

Concealed Rocks.

Just as the Dakota underlies the stratigraphically higher and younger formations which occur at the surface toward the west, so the Dakota is underlaid by older formations which appear successively at the surface to the east. One may study these older rocks either by driving eastward across the state or by examining records and samples of deep wells that have been drilled in Cloud and Republic counties.

A number of wells have been drilled. Records of two of the more recent ones in Republic county and three from Cloud county have been studied by Dr. J. W. Ockerman of the State Geological Survey, who plotted them as in the accompanying figure. The purpose of the plotting was to show the nature and thicknesses of the formations penetrated by the drill, rather than to indicate structure.

As will be seen from the sections, only the Murdock well (sec. 6, T. 6 S., R. 4 W.) began as high stratigraphically as the Jetmore beds of the Greenhorn limestone. The Walker well (sec. 23, T. 2 S., R. 1 W.) and Kouba well (sec. 24, T. 4 S., R. 2 W.) began practically at the top of the Dakota sandstone, while the Danielson well (sec. 1, T. 5 S., R. 1 W.) began in the lower shale member of the Dakota, and the Byrns well (sec. 3, T. 8 S., R. 1 W.) at the top of the middle sandstone.

The series of shales 300 to 400 feet thick, immediately below the Dakota, is assigned to the Wellington formation of the Permian. The base of this formation, which is so well marked by salt in wells farther south and west, is not as distinct in this area because the salt is missing. It is placed purely on lithologic evidence at the top of a heavy limestone series reached at a depth of between 600 and 700 feet. Absence of salt in the Wellington causes the formation to be much thinner than in wells to the south and west. The limestone unit, 500 to 600 feet thick, lying beneath the shale includes formations of the Marion, Chase and Council Grove groups. The Fort Riley limestone, which is prominent on the bluffs near Manhattan and other limestone beds exposed along the Blue river a short distance east of Cloud and Republic counties, occurs in these groups. Below the limestone series is a shale 500 to 600 feet thick containing a number of thin limestones, which is correlated with the

Wabaunsee, Shawnee and Douglas groups. The sandstone found at the base of this unit is thought to be equivalent to similar beds occurring at the base of the Douglas group in Douglas county. Also, in the Douglas group is the Oread limestone which caps the hill on which stand the buildings of the University of Kansas.

The heavy series of limestones, ranging from 500 to 600 feet in thickness, below the Douglas is correlated with the Lansing, Kansas City and Marmaton groups. The unusual percentage of thick limestones encountered by the wells corresponds to the thicknesses observed where these formations are exposed at Kansas City and elsewhere in the eastern part of the state. The base of the Pennsylvanian is reached at a depth of slightly more than 2,500 feet, or approximately 2,200 feet below the base of the Dakota formation. Only the Murdock well went into rocks older than the Pennsylvanian. It is believed from a study of the Murdock log that rocks of Mississippian age are absent in the area. The white and green shales in the last 400 or 500 feet may belong to a system of rocks as old as the Ordovician.

While there may be some question concerning the correlation of the units mentioned, there is general agreement on the placing of the base of the Cretaceous at the bottom of the sandstone, from 200 to 400 feet beneath the surface, and the placing of the base of the Pennsylvanian beneath the heavy limestone unit correlated in this report with the Marmaton-Kansas City-Lansing groups. Regardless of the age of the heavy limestone unit, it contains near its middle the Oswald limestone, from which oil is produced in Russell county. This horizon lies between 2,300 and 2,600 feet beneath the surface in Cloud and Republic counties.

GEOLOGIC STRUCTURE.

The geologic structure or attitude of the beds is important primarily in the accumulation of petroleum. The surface formations in Cloud and Republic counties have an average dip to the northwest of 10 to 12 feet per mile. There are areas, however, in which the beds dip on one side toward the west and on the other toward the east, as may be seen on the accompanying map. Elevations upon which the contours are based were obtained by means of an altimeter and were taken on the tops of the "shell rock" and "fence post" limestones, the two most satisfactory key horizons in the area. All elevations were checked with those shown on the topographic maps of the United States Geological Survey and each anticlinal

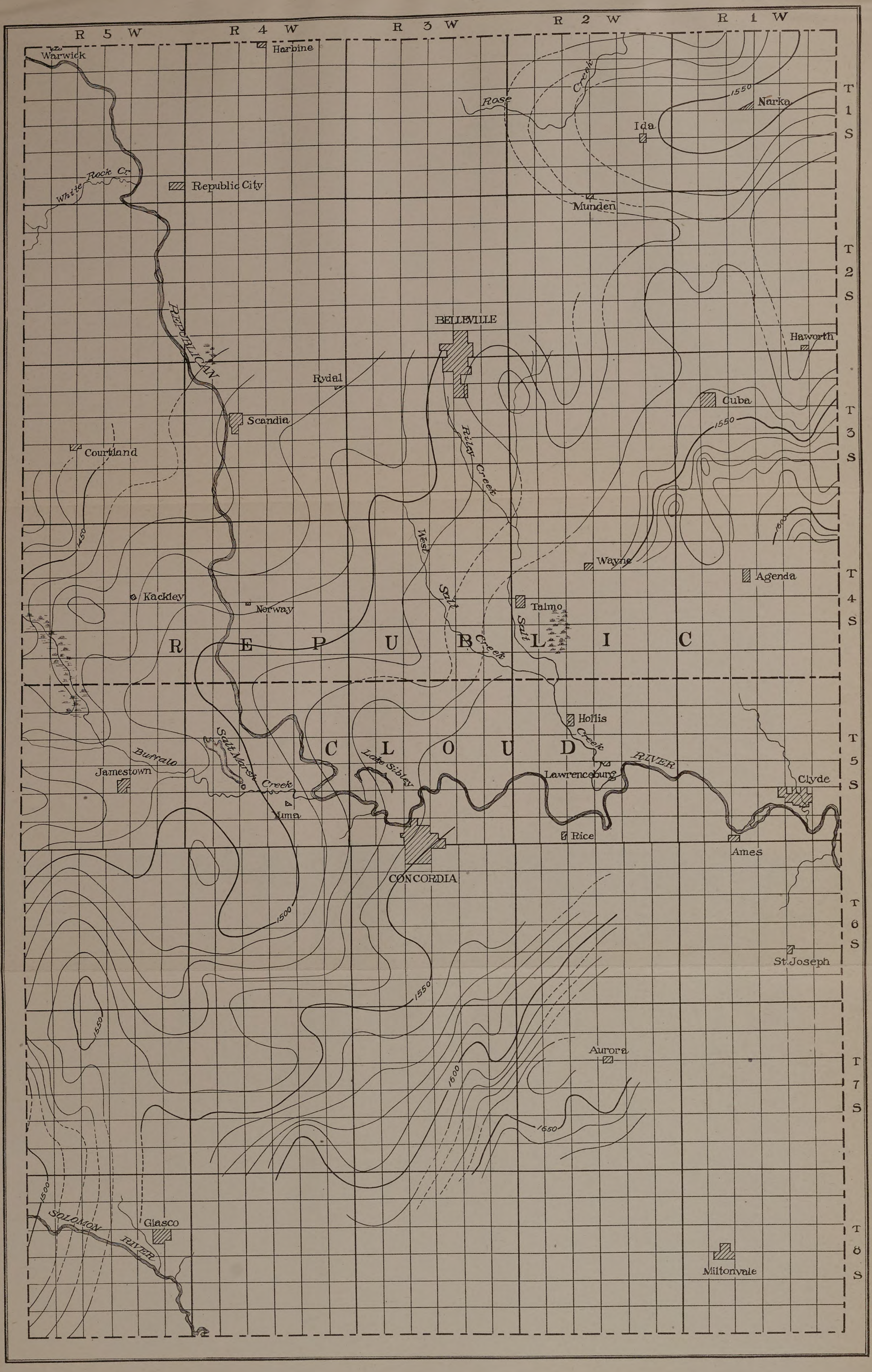

PLATE XVI.—Reconnaissance structural contour map of Cloud and Republic counties, Kansas.

structure was confirmed by observation of dips in the field. The structural map does not entirely cover the two counties, due to the fact that the southern and eastern parts of Cloud county and the eastern part of Republic county contain the Dakota formation at the surface, while the northern and western parts of Republic county are underlaid by Tertiary sand and clay. Neither the Dakota nor the Tertiary contains key beds suitable for use in structural mapping.

Reference to the map will show that there are a number of moderately prominent structures in both counties that may be considered favorable to the accumulation of oil and gas. These consist of anticlines trending toward the northwest but more or less in alignment with the regional northeast-southwest strike. Before any of these are considered seriously for drilling they should be surveyed in more detail.[16]

In Cloud county the most favorable structure extends diagonally from the southeast corner of T. 7 S., R. 5 W. to the northwest corner of T. 6 S., R. 5 W. The highest part of the structure is in secs. 32 and 33, T. 6 S., R. 5 W. and in secs. 4 and 5, T. 7 S., R. 5 W. The dip toward the west is unusually strong, while the difference in elevation of the beds to the northeast is 45 or 50 feet. The structure of the rocks to the southeast could not be determined, for reasons already stated, but there is some evidence that a similar favorable area exists in T. 8 S., R. 4 W. The exact location for a test well on a structure of this kind should be determined by a more detailed survey using plane-table and telescopic alidade.

Unusual dips toward the west and other data indicate another prominent anticline near the center of T. 7 S., R 2 W. Lack of outcrops prevented both the determination of the northern limit and the exact size of this structure, although a plane-table survey would add considerable detail.

A minor structure occurs in the northwest corner of T. 6 S., R. 4 W. This is the site of the McCullough well, which was drilled to a depth of over 3,595 feet without finding oil. A similar anticline is indicated by elevations obtained in the north central part of T. 6 S., R. 3 W. south of Concordia, but data were not sufficient to show its size or exact location. Favorable structures may occur in the Dakota sandstone area, also, but could not be determined from surface observations.

16. Recent investigations by J. W. Ockerman and me show that many of the surface anticlines in north central Kansas do not continue in depths below the Permian.—K. K. LANDES.

In Republic county the largest anticlinal structure occurs near the center of the west side of T. 1 S., R. 1 W. This is not only the largest structure of the entire area but is the most irregular in shape. The amount of the dip toward the west could not be determined, due to lack of outcrops, but the general dip of the beds in the region is in that direction. Toward the southeast the beds are at least 40 feet lower than at the top of the structure.

A well-defined but small anticlinal nose occurs in the northeast corner of T. 3 S., R. 3 W. Other small anticlines occur in section 21, T. 4 S., R. 5 W. and in the southwest corner of T. 3 S., R. 1 W. The area in the northwest corner of Republic county underlaid by Tertiary sand and clay was not surveyed because of the lack of beds upon which to take elevations. The region is underlaid, however, at relatively shallow depths by easily recognizable limestones, and consequently could be surveyed by means of the core drill.

ECONOMIC RESOURCES.

The mineral resources of economic importance in Cloud and Republic counties are gravel and sand, building stone, coal, clay, water and soil. Salt is of historic interest only, for the first salt produced in Kansas came from evaporating the natural brines of the salt marshes in this section.

Sand and Gravel.

Sand and gravel have a low unit value and for economic reasons cannot be transported far from the pit where they are produced. Consequently these materials are generally mined by the consumer or purchased by him directly from the producer. It is necessary, therefore, to develop as many widely separated deposits as possible, even though some of the deposits may not be large. The gravel and sand deposits of Cloud and Republic counties vary considerably in age. They are grouped in this report according to source of material and discussed in the order of their importance. Each deposit is described, and possible places where new supplies may be found are indicated.

GROUP 1.—RIVER AND FLOOD-PLAIN DEPOSITS.

A. REPUBLICAN RIVER. Sand and gravel are produced from Republican river at Scandia, Republic county, and from the flood plain at Concordia, Cloud county. Whether the material comes from the present channel, an old channel, or the flood plain it is the same in quality and consists of a clean quartz sand and gravel of excellent strength. The following analyses will serve to show the size of the material.

PLATE XVII.—Sand pump in pit near Republican river at Concordia, Cloud county.

Analyses of sand from old and present channels of the Republican river near Concordia, Cloud county.

Screen mesh.	—Percentage retained on screen— Old channel	Present channel
¼-inch	1.58	1.40
10-inch	9.88	19.80
20-inch	16.00	19.60
30-inch	28.62	20.15
40-inch	22.76	11.34
50-inch	13.27	9.56
80-inch	6.62	6.86
100-inch	0.42	0.57
200-inch	0.40	0.56

The flood plain and channel of Republican river constitute the largest single source of sand and gravel in Cloud and Republic counties. The supply is unlimited and of uniform quality along the entire sixty miles of the stream as it crosses the area. It can be produced cheaply by pumping, will wash and screen while wet, and is suitable for many purposes. The sand produced at Scandia is used for plastering, as fine aggregate in concrete, and in concrete blocks. The material produced at Concordia is used for road graveling after the finer material has been removed by screening.

B. Solomon River. Samples of sand and gravel taken from the bed of Solomon river near Glasco show that material of good quality may be produced from the channel of this stream at various places where it crosses the southwest corner of Cloud county. The material is coarser than that produced from the Republican river, due to the inclusion of fragments of local Cretaceous limestones. The finer material is composed primarily of quartz of excellent strength. The following analysis gives the size of material in a sample taken from a bar in the river near the southeast corner of sec. 8, T. 8 S., R. 5 W., west of Glasco.

Screen analysis of sand and gravel from Solomon river.

Screen mesh.	Percentage retained on screen.
¼-inch	25.81
10-inch	26.21
20-inch	18.05
30-inch	10.82
40-inch	9.16
50-inch	6.02
80-inch	2.74
100-inch	0.25
200-inch	0.30

Group 2.—Pleistocene River Gravels Near Glasco.

A. North of Solomon River. Extensive gravel and sand deposits occur in the Solomon river valley, both toward the northwest and southeast of Glasco. Some of the more important are as follows:

1. Chris Weaver, in the east center of the NW¼ NW¼, sec. 32, T. 7 S., R. 5 W.
2. Earl Sams, in the southwest corner of the SE¼, sec. 30, T. 7 S., R. 5 W.
3. Dave Funk, in the southwest corner of the SE¼, sec. 32, T. 7 S., R. 5 W.
4. Jim Hulse, in the SW¼, sec. 33, T. 7 S., R. 5 W.
5. Geo. Downey, in the center of the NW¼ NW¼, sec. 4, T. 8 S., R. 5 W.
6. Geo. Davidson, 100 yards east of Downey pit.

Other pits occur southeast of Glasco and occupy a position in the Solomon valley similar to those listed.

The deposits are essentially the same from place to place and consist primarily of quartz sand and gravel with a small percentage of larger fragments composed of local Cretaceous limestone. A slight amount of clay is present and some of the deposits contain minor amounts of calcium carbonate cement. All are of good quality, however, and the material is suitable for many uses.

The following screen analysis of sand and gravel from the Weaver pit, in the northwest corner of sec. 32, T. 7 S., R. 5 W., northwest of Glasco, will serve to show the coarseness of the material.

Approximate analysis of sand and gravel from the Weaver pit.

Screen mesh.	Percentage retained on screen.
½-inch	9
¼-inch	11
8-inch	19
14-inch	26
28-inch	19
48-inch	13
100-inch	1

Gravel and sand from the deposits listed have been used locally in concrete and for graveling roads, after a part of the fine material has been removed by screening. With the abundance of water in the region it should be easily possible to wash the material, and by proper screening make it suitable not only for use as fine aggregate in concrete paving but for many other purposes, also.

The deposit appears to be extensive in the region of the pits and southeast of Glasco. By extending the old pits and opening up new pits an almost unlimited quantity of material could be made available.

B.—South of the River. Two sand and gravel pits have been opened up in deposits of very similar material south of the river. One is on the Hugh Beck farm near the center of the west side of sec. 27, T. 8 S., R. 5 W., and the other on the Walter Butler farm near the center of the east side of sec. 2, T. 9 S., R. 5 W., directly south of Glasco. The material grades from fine sand to coarse gravel containing bowlders up to a foot in diameter. Both the large and small sizes of gravel are composed of local limestone and sandstone. The Beck pit particularly contains a relatively large amount of gravel and will serve a good purpose by supplying local needs. It is hardly suitable, however, for extensive graveling projects or for concrete paving, due to its large content of soft material.

Group 3.—Tertiary Sand and Gravel in Republic County.

The basal portion of the Tertiary formation in Republic county consists in places of sand and gravel. It is of moderately good quality and is produced north of Belleville from a number of pits.

The material consists of sand and gravel varying in size from very fine to pebbles ¼ inch in diameter. It is composed primarily of quartz with a small percentage of pink feldspar. The upper part of the deposit exposed in the pit is slightly clayey, but the base is moderately clean. The depth of the deposit ranges from a few feet to 10 or 12 feet. The gravel and sand produced is used locally in graveling roads and for construction purposes. The pits open at the present time are adequate to take care of local trade, but there is a possibility that many new pits may be opened up along the edge of the formation.

GROUP 4.—SAND DUNES.

Sand dunes are found at various places in the Republican river valley and along Otter creek in Republic county. A dune three miles northwest of Scandia has been mined for sand. Dune sand is uniformly fine-grained and is principally used in mortar and plaster.

Fence Posts and Building Stone.

"FENCE POST" BED. The "fence post" limestone has been quarried north and west of Glasco in Cloud county and at many places in Republic county. Quarrying is commonly done along the line of outcrop, where the overburden is thin and the rock not badly weathered. The bed varies in thickness from 6 to 9 inches and is moderately fine and chalky in texture. It is soft enough to permit considerable ease in quarrying, but hardens on exposure. It can always be identified at its outcrop or in a building or fence by its light creamy buff color, which grades into a darker buff band near the center.

The bed is quarried by uncovering the ledge for a distance of 6 or 8 feet from the outcrop, after which the rock is split into desired sizes by driving a row of wedges into it. For fence posts the rock is cut into strips about a foot wide and from 5 to 6 feet long. The wires are fastened to it by means of notches or drilled holes. Quarrying leaves a trench from 10 to 12 feet in width and 2 or 3 feet in depth in which water collects after a rain. Some of the older trenches are marked by a line of cottonwood trees which have grown as a result of the additional moisture. Other quarries may be traced by the narrow white ridge of waste material that is built up in uncovering the bed. Thousands of fence posts have been used in the area of the outcrop, not only in Cloud and Republic counties but in counties farther south and west. The rock has been used also in bridges and buildings, especially churches and schools. It is attractive when used in this way, particularly when rough trimmed.

JETMORE LIMESTONE MEMBER. Beds of the Jetmore limestone, particularly the "shell rock," have been quarried extensively in Cloud and to a lesser extent in Republic county. The more desirable "fence post" limestone bed is not widely exposed in Cloud county, so beds in the Jetmore are quarried instead. As with the "fence post" limestone, quarrying is confined to the brow of the hill or on the slopes where the limestone is covered to a depth of only two or three feet and is not badly weathered.

The lower beds of the Jetmore vary in thickness and texture, but the "shell rock" may be as much as 9 inches thick and of fairly uniform texture. The "shell rock" is soft enough to be worked easily and yet it hardens on exposure to the atmosphere, becoming moderately resistant to wear. It is gray or white in color. It has been used in fences, bridges, foundations and even in buildings.

DAKOTA SANDSTONE. Sandstone from the Dakota has been quarried in a number of places and used in buildings. More extensive use has been prevented by its lack of uniformity in color, texture and hardness. It is too hard at some localities to be trimmed easily; in others it is too soft to withstand wear. The irregular texture of the Dakota sandstone does not permit the cutting of even blocks, while its color varies, even in one quarry.

Coal.

Production of coal was begun in Cloud and Republic counties at Minersville between Concordia and Belleville as early as 1855 and was continued down to relatively recent times when cheaper transportation brought insurmountable competition from eastern Kansas fields. At no time was production large, and yet coal played an important part in supplying local needs and in the development of the two counties. Present inhabitants can remember when teams came from points 20 and 30 miles distant to the mines and lined up at daybreak to receive the coal as it was brought to the surface.

The name of Curtis has been associated with the industry from its beginning. Curtis and Henderson opened up the first mine in pre-Civil War days, while some of the mining just before the World War was done by Don and Dick Curtis. Murray, Henderson and Struthers also were active in the coal-mining industry. The peak of production was reached in 1894 and 1895 when at least eight companies were operating in the field and the production for Cloud county reached 5,000 tons (1895) and 8,242 tons for Republic county (1894).

The mines range in depth from 30 to 110 feet. The deeper mines begin near the base of the Jetmore limestone member and pass through approximately 90 feet of blue shale belonging to the lower Greenhorn member and the Graneros. The coal is found approximately 12 feet below the top of the upper sandstone member of the Dakota. The lower foot of the sandstone, which forms the roof for the coal, is firmly cemented with iron.

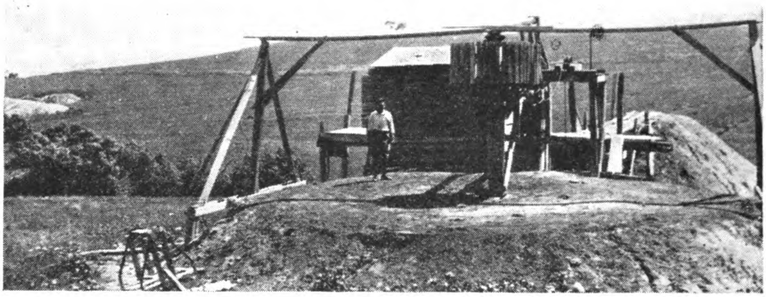

PLATE XVIII.—The last coal mine to be opened at Minersville, Cloud county, NE¼, sec. 2, T. 5 S., R. 3 W.

The coal consists of black lignite having the following composition: Water, 13.7 per cent; volatile matter, 46.14 per cent; fixed carbon, 28.52 per cent; and ash, 11.64 per cent. It occurs in two layers separated by a maximum of 4 inches of "black jack" or impure coal. The upper layer is 8 inches thick and contains slightly more sulphur and burns more quickly than the lower layers. The lower layer is a foot thick. Both beds burn leaving no soot but a considerable quantity of white ashes similar to those of wood. The coal thickens and becomes deeper to the west. It has been mined principally by the vertical-shaft method, although in some places a sloping shaft has been used. At a few localities the coal has been removed directly from the outcrop of the bed along the creeks.

Clay and Shale.

Clay and shale consist of the finest and most insoluble products of weathering. The chief distinction between the two is that clay is less consolidated and does not have the cleavage of shale. There are all gradations, however, and since the two share many uses the terms are used more or less interchangeably. The most important use is in making common brick and tile.

Kansas is a large producer of brick and tile. The clay industry has been located chiefly in the eastern part of the state, due to a combination of favorable conditions including the presence of suitable shales, cheap fuel for burning, and a near-by market. However, the discovery of gas in western Kansas and the piping of this commodity into communities in northern Kansas removes one of the handicaps to the brick-and-tile industry in this part of the state. Local markets will develop, so the only remaining condition for establishing the industry is to find suitable raw material.

The two most favorable deposits in Cloud and Republic counties are the loess of Pleistocene age and the shale of the Dakota formation. The former is a silty deposit of very wide occurrence over the uplands and bluffs of both counties. It is probably the source of the material used in the brick plant at Concordia, which was in operation for a number of years. The Dakota outcrops along the eastern side of Cloud and in the southeastern part of Republic county. Although the formation contains thick beds of sandstone and some of the shale is sandy, it is believed that many places can be found where the shale is suitable for making brick.

Brick and tile require a clay of moderately definite chemical and physical properties, some of which can be determined in the field while others require careful laboratory analysis. Plasticity and texture can be judged by kneading the clay between the fingers. These properties are important in determining whether or not the clay can be molded into desired shapes which it will maintain. The clay should not contain a very large percentage of calcium carbonate, especially in the form of nodules, nor silica in large grains. Other important factors in considering the exploitation of a deposit of clay or shale are the size of the deposit and the amount of overburden (material that will have to be removed before the shale or clay can be recovered). Obviously closeness to market and transportation facilities should be carefully considered.

Water Supplies.

Water, where plentiful and of good quality, constitutes one of the most important resources of a region. Less interest commonly is shown in the water supply, however, where it is abundant than where it occurs in limited quantities. Cloud and Republic counties have large areas in which the supply can be classed as unlimited, of excellent quality, and easily obtainable, but in relatively small areas in the two counties water is scarce, or of poor quality. The water resources of Cloud and Republic counties will be discussed according to source.

SURFACE WATER.

Surface water comes primarily from precipitation in the form of rain and snow, and secondarily from seepage of ground water. The former is more important in the flow of water from the uplands, while the latter causes the continuous, steady flow of water in the streams. Cloud and Republic counties are drained by Solomon and Republican rivers and their tributaries. Both rivers flow from the west through water-bearing formations, and consequently their supply is fairly uniform.

The hill slopes and smaller creeks carry water only during and directly after a rain. The amount of water running off over the surface at any one place depends not only on the character and amount of rainfall but also on the steepness of the surface and the porosity of the underlying soil. Where the slope is steep a greater percentage of the rainfall will join the surface run-off. The same will occur where the underlying soil is clayey or relatively impervious. Ponding this run-off is a simple engineering problem and would supply ample water for farm use. The rainfall is sufficient and other conditions favorable so that no farm in Cloud or Republic counties need be without stock water.

GROUND WATER.

RIVER GRAVEL. Cloud and Republic counties are drained by two of the principal tributaries of Kansas river. Solomon river, in southwestern Cloud county, has a flood plain over 3 miles in width, and Republican river, with 30 miles of its course in the western part of Republic county and 30 miles in the northern part of Cloud county, has a flood plain between 2 and 3 miles in width. The flood plain of a stream is the flat valley bottom. It contains, beneath the surface layers of soil and silt, sand and gravel ranging in depth from a few feet up to 60 feet. The sand and gravel in the flood plains of Solomon and Republican rivers obtain a plentiful supply of water through movement down the valley from the west and through seepage from near-by uplands. The material is sufficiently coarse to yield its water readily. Wells producing from flood-plain deposits are assured an unlimited supply that will never fail.

Wells on the flood plains range in depth from a few feet to 20. The deeper wells are on the terraces. The depth to the top of the water is slightly less than the difference in elevation between the place where the well is located and the surface of the water in the river. Many of the wells can be driven, due to the slight depth and the nature of the rock.

SHEET WATER FROM THE UPLANDS AND SLOPES. Sheet water is ground water that occurs in the soil and slope wash above an impervious bed-rock surface. Thus the shale underlying the uplands in Cloud and Republic counties catches the water percolating down from the surface and prevents it from sinking farther. Because the surface of the shale is not level the water collecting above it will move in the direction of slope, which is generally toward the valleys. The soil veneer above the bed rock has a maximum depth of 40 feet. Wells producing sheet water are dug instead of drilled.

The amount of water obtainable from this source is obviously not great. It depends on the amount of water seeping down from the surface, the porosity of the soil, the degree of concentration of the flow into drainage channels on top of the shale, and the amount withdrawn by local wells. The supply of sheet water has diminished in recent years either because the amount of rainfall has been less or because run-off and withdrawal have been greater, due to settling of the country. This decreased supply has created a critical condition where sheet water is the only water obtainable. While the amount of water in the soil cannot be increased, the conditions under which it occurs will permit much more water to be recovered from the wells than is now obtained. In prospecting in this area an attempt should be made to find those places where the coarse soil or gravel overlying the bed rock is thickest. This can be done by noting the thickness and porosity of the basal materials in each well drilled and locating new wells in the direction toward which the gravels thicken. Also, careful records of the depth to the underlying impervious shale should be kept with the idea of locating new wells where there are depressions or ravines at the top of the shale. Not only may the gravels be thicker in such places, but the sheet water tends to work its way toward them just as it does at the surface. In most cases these channels occur beneath similar ones on the surface, but undoubtedly others exist which have no relation to the present drainage. Where the channels in the shale lie beneath those on the present surface, the greatest supply of water may be expected beneath the fill in the creek bottoms. The supply in any one well may be materially increased by digging the well down to the bed-rock surface and by running tunnels along the top of the shale at right angles to the movement of the water.

TERTIARY GRAVEL. The Tertiary gravel, sand and clay deposits in the northern part of Republic county have already been described. They provide an excellent supply of water, particularly in the old channel between White Rock and Chester. The wells in this relatively narrow belt are drilled to the top of the shale ("slate") where casing is set. The wells near the Republican river are relatively shallow, but in the higher parts of the Tertiary area the wells range between 160 and 220 feet in depth. Part of the water filling this channel undoubtedly comes from the neighboring slopes, but the major part comes from drainage into the channel from Republican river and other sources farther west. The water is of excellent quality and unlimited in amount. The new city wells at Belleville obtain their supply from this source.

The surface of the blue shale outside of the channel is higher and the supply of water is not so plentiful. In fact, the farther the well is located from the channel the higher the shale, the thinner the gravel, and the less the water. The same suggestions that were made in regard to obtaining increased supplies of sheet water apply to wells drilled in the Tertiary outside of the channel. Undoubtedly many of the wells that already produce a plentiful supply have penetrated into tributary channels leading northward into the main channel. Others may be discovered by noting the slopes of the top of the shale as told from the depths of wells drilled.

DAKOTA SANDSTONE. The Dakota sandstone is the principal water-bearing formation in the Great Plains area. It consists of thick beds of sandstone separated by beds of shale. In general, the formation outcrops in a relatively narrow, irregular belt encircling the Great Plains and is covered by younger formations in the center. The western outcrop in Colorado, Wyoming and South Dakota is higher, so that water entering the formation along this belt tends to migrate toward the east. The water in the central part of the area occurs under considerable pressure, so that many of the wells flow. Numerous springs occur along the eastern outcrop of the formation. Two types of water are produced from sandstone members of the Dakota. Careful studies of the flow of water from each sandstone member in North Dakota, South Dakota and Minnesota have shown that certain of the beds, principally in the upper part of the formation, produce soft water while the lower members yield hard water.

The Dakota underlies all of Cloud and Republic counties. It is at the surface to the east and in the principal valleys, but younger formations overlie it on the uplands. Attempts to obtain water supplies from this formation have met with varying degrees of success. Some of the wells yield an abundant supply of palatable water. The only difficulty in others lies in preventing the pumping of fine sand with the water. This can be overcome by proper screening and pumping. But in some of the wells the water contains so much salt, gypsum and iron that it cannot be used, even for watering stock. Whether this condition is a local one with all the principal sandstones in the formation yielding salt water or whether this objectionable water comes only from certain beds cannot be determined from data at hand. It seems to the writer, from experience gained elsewhere and through knowledge of the conditions existing in the Dakota, that the wells yielding fresh water produce from different beds than those in which the water is salty. This offers the hope that fresh water may be produced in any locality from the Dakota if the driller will very carefully obtain and test unadulterated samples of water from each and properly case off the strata producing salt water. The discovery of fresh-water horizons in localities where the Dakota has heretofore produced only salt water and where water from other sources is insufficient would be of great value.

Where the Dakota sandstone outcrops the water obtained is clear and fresh, due to leaching of the salt by water which has seeped in from the surface.

Soils.

The soil in an agricultural community is an important economic resource. Cloud and Republic counties, with their exceptionally large acreage of "bottom land" and broad flat uplands underlaid by silty loam, are exceedingly well endowed with fertile soil.

Soil is the result of decay and disintegration of rock, and consists chiefly of silt, sand and larger rock fragments, organic matter, and a varying quantity of compounds such as kaolin and calcium carbonate. It varies, not only in its composition, but also in its thickness, color, and other physical properties. The chemical composition depends primarily upon the composition of the source rock, but the organic life present, the climate, and the slope of the surface also affect the character of the soil. Plants and borers such as worms and insects have an important effect on the composition, color, and drainage of soil. Climate, which includes wind, precipitation, and temperature, affects the amount of weathering of the bed rock, the amount of sediment that is shifted from one place to another and the amount of organic material and lime present. The rainfall in Cloud and Republic counties has been such that the soil contains a moderate amount of organic matter, and the lime has been leached only from the upper soil and is found concentrated at the base of the subsoil. The slope of the surface affects the thickness and nature of the soil. Soil derived from foreign materials may be present on the flat uplands and in the valleys, while on the slopes bed rock is exposed and the soil is thin.

The most important factor, however, in determining the nature of soil is the character of the rock or material from which it is derived. The sources of soil in Cloud and Republic counties are listed in the order of their importance and the resulting soil briefly described.

(1) *Loess.* Soil derived from the loess overlies most of the upland flats in both Cloud and Republic counties. The soil is a grayish silt loam. It contains some calcium carbonate and is one of the best soils in the area.

(2) *Alluvium.* The alluvial deposits underlying the flood plains of Solomon and Republican rivers and some of their larger tributaries have produced the best soils in the area. They consist of fine sand and silt loams. Drainage on the lower part of the flood plain is poor, but in the higher areas, particularly on the terraces along Republican river, it is much better.

(3) *Carlile shale.* A considerable part of the soil of the uplands in Cloud county and in relatively small areas in Republic county is derived from the Carlile shale. It consists of reddish clay soil grading into silt loam where the loess is more prominent. The lower 200 feet of this shale produces better soil than the upper, due to its calcium carbonate content. The shale is relatively impervious, and drainage through it is poor.

(4) *Slope wash.* Extensive areas in Republic county, both gently sloping uplands and valleys, are underlaid by clays and sands washed from the Tertiary formation. The soils here vary from

clayey to sandy and are very similar to those derived from the Carlile shale.

(5) *Tertiary sand and clay.* The soil contains sand near the border of the Tertiary deposits where the overlying loess has been cut away, especially along the creeks. The sand is in part clayey and contains little lime except where mixed with loess. It consequently ranges from red to gray in color.

(6) *Dakota shale members.* The Dakota shale members weather to gentle slopes except where capped by protecting ledges of sandstone. The soil on the gentle slopes is a sandy silt loam containing some wind-blown material, while beneath the sandstone caps it is clayey and thin. Fortunately the latter areas are relatively small.

(7) *Lower Greenhorn and Graneros shales.* These formations outcrop on the slopes beneath the Jetmore limestone member. Consequently the soil is clayey and thin. Surface drainage is good, but drainage below very poor.

(8) *Jetmore limestone and Pfeifer shale members.* The soil is clayey and in places rocky. Due to the steep slopes where the Jetmore limestone member outcrops the soil is relatively thin.

(9) *Dakota sandstone members.* The soil developed from these members ranges from a sandy loam on gentle surfaces to a rocky soil on steep slopes.

The soils derived from the loess and alluvium are the best in the area, while those derived from shales outcropping on moderately flat surfaces are a close second. Fortunately most of the soil in each county falls into one of these classifications.

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